New camaenid land snails from the northeast Kimberley, Western Australia

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ABSTRACT

Seven new species and subspecies of camaenid land snails from northeastern Western Australia are described or discussed. The species all have very restricted ranges, and are found near the Northern Territory border in the area from both sides of the Cambridge Gulf in the north, to the hills lying southeast of Turkey Creek. The six described species and subspecies are: *Amplirhagada cambridgensis* from the Lyne River on the west side of Cambridge Gulf; *Amplirhagada osmondi* from the Osmond Range-Palms Yard area southeast of Turkey Creek; *Ordtrachia elegans* from an isolated outlier of the Jeremiah Hills northeast of Kununurra; *Ningbingia australis elongata* and *Cristilabrum rectum* from the Ningbing Ranges north of Kununurra; and *Mesodontrachia cockburnensis* from the Cockburn Range southwest of Wyndham. Another probable new species of *Cristilabrum* from the Ningbing Ranges currently is represented by very limited material. It is not described at this time, but is illustrated for future-reference.

INTRODUCTION

The camaenid land snail fauna of the Kimberley has been revised recently in a series of monographs (Solem, 1979, 1981a, 1981b, 1984, 1985b), which recorded 137 species, compared with the 17 listed by Hedley (1916: 68-70) and 32 reviewed by Iredale (1939: 46-73). Despite this increment, I stated ". . . it is probable that at least a doubling of species numbers will occur when other parts of the Kimberley are explored for land snails" (Solem, 1985b: 976). This prediction was based upon the facts that most of the known species show very restricted ranges, and much of the Kimberley remains uncollected.

This paper begins the process of naming additional taxa.

The species described below were discovered in the course of 1980 and 1984 field work by the author, and a survey of the Bungle Bungle area and neighbouring regions by Phil Colman and Vince Kessner in 1986. The latter trip was sponsored by the Australian Museum, Sydney. A number of additional new species have been discovered, but their description is postponed pending further study. Documentation of the few species described here is a necessary prelude

to summarizing the biogeography and variation of the amazing land snail radiation in the Ningbing Ranges.

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The following abbreviations indicate the repository of cited specimens:

AM	Australian Museum, Sydney
FMNH	Field Museum of Natural History, Chicago
VK	Private collection of Vince Kessner, c/o Dept. of Health, Darwin, NT
WAM	Western Australian Museum, Perth

Where material permits, synoptic sets of paratypes will be deposited in the Museum of Victoria, Queensland Museum, and South Australian Museum.

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SYSTEMATIC REVIEW

Data concerning the range of shell variation (Table 1) and patterns of local population variation (Tables 2-3) should be compared with the relevant tables in Solem (1981a, 1981b, 1984, 1985b). Cross reference is given to comparative figures in these reports rather than reproducing illustrations. Plates 1-3 record basic shell sculpture and some details of the few radulae that show unusual features. Comments that place these species within generic phylogenetic and biogeographic contexts precede the individual descriptions.

Specimens from each station are listed as to number of live adults (LA), dead adults (DA), live juveniles (LJ), and dead juveniles (DJ). Latitude and longitude coordinates are provided for each station as an aid to relocating the exact populations. Anatomical abbreviations on the text figures are the standard ones used in previous monographs in this series (Solem, 1979, 1981a, 1981b, 1984, 1985), and usually are included in the text concerning that dissection.

Genus *Amplirhagada* Iredale, 1933

The monograph of *Amplirhagada* (Solem, 1981a: 148-320) has been supplemented by a few additional records (Solem, 1985b: 935-940). Patterns of shell and radular variation in species of the Napier Ranges, where *Amplirhagada* becomes sympatric with *Westraltrachia*, have been reviewed

separately (Solem, 1985a). The latter paper documents the dramatic conchological changes that may occur as the result of sympatric species interactions.

Key structures in recognizing species of *Amplirhagada* are found in the penis chamber, with the main stimulatory pilaster (PT, Figs 7-8, 10-11) usually being diagnostic. Variations in shell colour, shape, and sculpture generally are subtle, with many convergences. The greatest variation in pilaster structure occurs when species are microsympatric (Solem, 1981a: 171-176, figs 36-37). Allopatric taxa would not be subject to selection pressure for such structural alteration. Thus the strong similarity in pilaster sculpture between *A. cambridgensis* (Fig. 8) and *A. osmondi* (Fig. 11) may indicate retention of a generalized feature. The differences in their pilaster widths and lengths (Figs 7, 10) are equivalent to differences found between many West Kimberley taxa that are microsympatric.

There is a distinct difference in radular structure between *Amplirhagada cambridgensis* (Plate 2c-d) and *A. osmondi* (Plate 2e-f). The former has the cusp tip less curved, the point sharper, the cusp angle lower, and there is a more gradual transition between lateral and marginal teeth. In *A. osmondi,* the cusp shaft has a higher angle, the tip is blunter and more sharply curved, the ectocone is less prominent, and there is a rather abrupt transition between lateral and marginal teeth.

Amplirhagada cambridgensis has the more generalized structure. Its habitat is shared with a larger camaenid, *Xanthomelon obliquirugosa* (Smith, 1894), that apparently aestivates by burrowing down into the soil. The Lyne River area almost certainly has a longer wet season with a greater amount of rain than is found in the area where *A. osmondi* lives. The latter species occurs with an as yet unnamed species of *Ordtrachia,* which is smaller in size. The altered tooth structure of *A. osmondi* may indicate feeding specialization in what probably is a more stressful habitat.

Both species provide a notable change in generic range over that mapped previously by Solem (1981a: 316, fig. 73). *Amplirhagada cambridgensis* extends the range east from the Drysdale River almost to Cambridge Gulf, while *A. osmondi* lives significantly southeast of the Chamberlain-Pentecost Rivers junction, the previous southeasternmost record.

Amplirhagada cambridgensis, new species (Plates 1a, 2c-d; Figs 1-3, 7-8)

Comparative remarks

Amplirhagada cambridgensis, new species, from the Lyne River basin on the west side of Cambridge Gulf, is a relatively large (mean diameter 19.99 mm), narrowly umbilicated (Fig. 3) species, with rather high spire (Fig. 2), and a faint trace of a narrow, slightly supraperipheral, spiral colour band. A weak lip node is present (Fig. 2). The rounded shell periphery and relatively strong radial sculpture (Plate 1a) are obvious differences from *A. drysdaleana* Solem (1981a: 185-188, pl. 12d, figs 38c-d) from the Drysdale National Park, and *A. questroana* Solem (1981a: 188-194, pl. 12e, figs 38a-b) from near the junction of the Chamberlain and Pentecost Rivers, southwest of Wyndham. *A. osmondi,* new species, from southeast of Turkey Creek, has different proportions (Table 1), and usually a more open umbilicus (Fig. 6), a slightly angulated periphery (Fig. 5), much weaker lip node and reduced radial shell sculpture (Plate 1b), plus a stronger supraperipheral colour band and a prominent subsutural red colour band (Fig. 5). Anatomically, the vagina (V) is very short (Fig. 7), penis about equal in length to the penis sheath, verge (PV) rather large, main pilaster (PT) tapering for most of length and with only weak traces of nodes on the corrugations (Fig. 8). *A. drysdaleana* (Solem, 1981a: 186, figs 39a-b) has the penis much longer than the sheath, the verge reduced, the main pilaster consisting of one row of very large pustules, and a very long vagina. *A. questroana* (Solem, 1981a: 193, figs 40a-b) has a very short and broad main pilaster without nodes on the corrugations, smaller verge, but agrees more in basic wall pustulations and vaginal length. *A. osmondi* (Figs. 9-11) has a longer vagina, very narrow verge and main pilaster, plus coarser wall pustulations. *A. kalumburuana* Solem (1981a:204, figs 44a-c) differs in having sharp points on the main pilaster, a very long vagina, and the long penis coiled within the penis sheath.

Holotype

WAM 142.84, Station WA-985, north branch Lyne River, west side of Cambridge Gulf, East Kimberley, Western Australia. 14° 48' S, 128° 02' E. Medusa 1:100,000 map sheet 4568 — 957:631m. Collected 23 May 1984 by Alan Solem, Laurie Price, and Ken Emberton. Height of shell 14.45 mm, diameter 20.2 mm, H/D ratio 0.715, umbilical width 0.75 mm, D/U ratio 26.9.

Paratopotypes

WAM 143.84, FMNH 211718-9, 6 DA, 3 LJ, 6 DJ from the type locality.

Diagnosis

Shell 18.7-20.95 mm (mean 19.99 mm) in diameter, with 5⅝- to 6⅛- (mean 5⅞-) normally coiled whorls. Apex and spire moderately and evenly elevated, height of shell 12.05-14.85 mm (mean 13.80 mm), H/D ratio 0.633-0.729 (mean 0.689). Apical sculpture (Plate 1a) weak, low and irregular radial ridglets present on early spire, changing to prominent and sharply defined ribs on lower spire and body whorl above periphery, base of shell nearly smooth. Shell periphery (Fig. 2) rounded. Body whorl very slightly descending behind lip, which is thin, moderately expanded (Figs 1-3) and with a low basal node (Fig. 2). Umbilicus (Fig. 3) almost completely covered by reflection of shell lip in adults, very narrowly open in juveniles, width 0.6-2.0 mm (mean 1.11 mm), D/U ratio 14.3-31.7 (mean 19.1). Shell pale in colour, a very faint supraperipheral reddish spiral band visible in freshest examples. No trace of other colour markings. Based on 7 measured adults.

Terminal genitalia (Figs 7-8) with relatively short vagina (V), free oviduct (UV) and spermatheca (S). Vas deferens (VD) entering penis sheath (PS) at apex, reflexing to receive insertion of penial retractor muscle (PR), then coiled down to the point where it enters head of penis (P). Penis chamber (Fig. 7) with very small verge (PV), wall pilasters typical. Main stimulatory pilaster (PT, Figs 7-8) slender for most of length, enlarged only near apex, corrugations with only weak projecting tips. Central and lateral teeth of radula (Plate 2c) with moderate anterior flare, small ectocone, mesocone with sharp tip, and slight curve to cusp. Basal ridge prominent. Transition from lateral to marginal teeth gradual (Plate 2d).

Discussion

The holotype of *Amplirhagada cambridgensis* was the only live adult found. A window was broken into the body whorl (Figs 1-3) in order to extract the terminal genitalia for study. The structure of the small main pilaster (Figs 7-8) is very different from any of the West Kimberley species (Solem, 1981a: 172-173, figs 36a-f, 37a-i), and serves to characterize this species.

The west bank of Cambridge Gulf, as viewed from a helicopter, is relatively inhospitable looking snail country. There are very few talus accumulations visible even in the gorges, most slopes are without rock protrusion, no limestone formations were spotted, and the whole area has sparse tree cover. The type locality of *Amplirhagada cambridgensis* also yielded 14 dead examples of *Xanthomelon obliquirugosa* (E. A. Smith, 1894) (FMNH 211721), but no other land snails. A stop at a likely looking hillside along the Berkeley River near the Campbell Range (ca 14° 37' 30" S, 127° 06' E) resulted in finding only "snail-free" rock piles.

It will be very surprising if thorough surveying of this region fails to locate additional colonies and species, but the countryside from east of the Drysdale River to Cambridge Gulf probably has only scattered colonies of camaenid land snails.

The name *cambridgensis* refers to the location of the species within the drainage basin of Cambridge Gulf.

Amplirhagada osmondi, new species (Plates 1b, 2e-f; Figs 4-6, 9-11)

Comparative remarks

Amplirhagada osmondi, new species, from the upper Osmond and Red Rock Creek drainages, located south-southeast of Turkey Creek, East Kimberley, is a larger than average species (mean diameter 19.32 mm), narrowly umbilicated (Fig. 6), with moderately elevated spire (Fig. 5), and

prominent subsutural and supraperipheral colour bands. A small lip node is present in some populations. The bright colour bands and general proportions agree with *A. questroana* Solem (1981a: 188-194, pl. 12e, figs 38a-b), but the latter has much stronger radial sculpture and the basal lip always lacks a node. *A. drysdaleana* Solem (1981a: 185-188, pl. 12d, figs 38c-d) is much smaller, has a much more angulated periphery, and no basal node. *A. kalumburuana* Solem (1981a: 202-205, pl. 12f, figs 43c-d) shows a number of minor shape and colour differences. Anatomically, the very short vagina (V, Fig. 9), penis (P) essentially equal in length to the penis sheath (PS, Fig. 10), thickened spermathecal base (S), larger verge (PV, Fig. 10), and elongated main pilaster with weakly knobbed corrugations (PT, Figs 10-11) are diagnostic. Of the neighbouring species, *A. drysdaleana* Solem (1981a: 186, figs 36a, 39a-b) has a very long vagina, the long penis is coiled within the penis sheath, and the main pilaster consists of a single row of large tubercles with anterior points; *A. questroana* Solem (1981a: 193, figs 37a, 40a-b) has a longer vagina, the penis equal in length to the penis sheath, and a very broad main pilaster with only a few centrally located blunt points on the corrugations; and *A. kalumburuana* Solem (1981a: 204, figs 37b, 44a-c) has a very long vagina, the penis much longer than the sheath, and a main pilaster with more prominent points than in *A. questroana*. *A. cambridgensis*, new species (Figs 7-8) has a medium length vagina, small verge, and a greatly reduced main pilaster.

Holotype

AM C.150373, Station PC-52, 33.7 km southeast of Palms Yard, near Red Rock Creek, southeast of Turkey Creek, Kimberley, Western Australia. 17° 18′ S, 128° 26′ E. Collected 26 May 1986 by Phil Colman and Vince Kessner. Height of shell 12.6 mm, diameter 18.8 mm, D/U ratio 0.670, umbilical width 1.1 mm, D/U ratio 17.1.

Paratopotypes

AM C.150373, VK 9344, FMNH 205923, 2 LA, 16 DA, 8 DJ from the type locality.

Paratypes

East Kimberley: Palms Yard Outstation (PC-43, 17° 14′ 30″ S, 128° 15′ 30″ E, 25 May 1986, AM C.150366, VK 9338, FMNH 215266, 12 LA, 19 LJ, 19 DA, 6 DJ); 3.3 km east of Palms Yard (PC-44, 17° 14′ 30″ S, 128° 17′ E, 25 May 1986, AM C.150361, VK 9339, FMNH 205924, 1 LA, 35 DA, 7 DJ); 6.2 km east of Palms Yard (PC-45, 17° 14′ 30″ E, 128° 18″ E, 26 May 1986, AM C.150379, VK 9340, WAM 144.84, FMNH 205925, 5 LA, 55 DA, 7 DJ); 8.9 km east of Palms Yard (PC-46, 17° 14′ S, 128° 19′ E, 26 May 1986, AM C.150417, 3 DA, 2 DJ); 19.4 km east of Palms Yard (26 May 1985, VK 9341, 8 DA, 1 DJ); 30 km east of Palms Yard (26 May 1986, VK 9343, 2 DA, 1 DJ); Bungle Bungle Outstation (PC-53, 17° 20′ 30″ S, 128° 20′ 30″ E, AM C.150424, VK 9342, 10 DA, 2 DJ); 2 km from turnoff to Bungle Bungle Outstation (PC-54, 17° 24′ S, 128° 18′ E, 27 May 1986, AM C.150425, 6 DA, 2 DJ); Spring Creek, 7 km north of Ord River crossing of Great Northern Highway (PC-55, 17° 27, S, 127° 58′ 30″ E, AM C.150367, 2 LA, 1 LJ).

Range

Amplirhagada osmondi has been found within a small area of the upper drainages of Osmond Creek and its tributary, Red Rock Creek, between Palms Yard and Bungle Bungle Outstation, plus an outlying locality at Spring Creek, southwest of Turkey Creek. These records are included within a triangle of 40x15x35 km, lying in the upper west Ord River drainage.

Diagnosis

Shell variable in size, 14.2-22.5 mm (mean 19.32 mm) in diameter, with 4⅞+ to 6⅜+ (mean 5¾+) normally coiled whorls. Apex and spire moderately elevated, often slightly rounded above, height of shell 8.3-15.65 mm (mean 12.59 mm), H/D ratio 0.557-0.758 (mean 0.650). Apical sculpture (Plate 1b) weak, inconspicuous and irregular radial ridglets on spire and body whorl, joined by weak incised spiral lines on body whorl. Shell base nearly smooth. Shell periphery (Fig. 5) rounded to weakly angled. Body whorl descending very slightly behind lip, which is thin, narrowly expanded, partly reflected over umbilicus, sometimes with a very small basal node present. Umbilicus (Fig. 6) generally narrowly open, partly to nearly completely covered by reflected lip, width 0.6-2.0 mm (mean 1.28 mm), D/U ratio 9.71-33.2 (mean 15.7). Shell pale yellow horn in colour, with narrow,

bright red, subsutural and supraperipheral spiral bands. No columellar colour patch. Based on 173 measured adults.

Genitalia (Figs 9-11) typical of *Amplirhagada*, vagina (V) very short, base of spermatheca (S) swollen. Free oviduct (UV) long, not coiled. Vas deferens (VD) entering penis sheath (PS) at apex, reflexing to receive insertion of penial retractor muscle (PR), coiled to head of penis (P). Penis sheath (PS) with walls of lower half thickened, very thin in upper half. Verge (PV) typical in size and shape. Penis chamber (Fig. 10) with typical wall pustulations and a prominent main pilaster (PT) that has a few blunt points edging the corrugations (Fig. 11).

Central and lateral teeth of radula (Plate 2e) with blunt tipped, curved mesocone, high cusp shaft angle, tiny ectocones, and massive basal ridge. Transition between lateral and marginal teeth abrupt (Plate 2f).

Discussion

Amplirhagada osmondi shows considerable variation both within and among populations. Size and shape differences are summarized in Table 2. The size variation is mosaic rather than linear, and probably involves differences in cessation of growth timing. Thus the samples from Palms Yard and 19.4km east of Palms Yard have small diameter and reduced whorl counts compared with other populations. There is more than a 4 mm difference in mean diameters among populations sampled, with mean whorl counts ranging from 5¼+ to 6+. As would be expected, small adults tend to have greater angulation on the body whorl than do the larger adults. I anticipate that there are differences in moisture retention among the sites collected, resulting in increased or decreased activity time, which controls growing time, and thus eventual adult size. Shape differences (Table 2) are minor. Larger shells have greater H/D ratios, which correlates with the increased whorl counts of larger shells. Individual differences in body whorl descension behind the lip are greater within populations than between populations.

Presence and degree of development of a basal lip node also is variable. The small sized adults, with rare exceptions, lack any trace of the node, while most of the larger individuals from Bungle Bungle Outstation have a small, but sharply defined node near the basal-columellar margin. Specimens from 3.3 and 6.2 km east of Palms Yard have less prominent to no trace of such a node.

Interpretation of the above variation will require much additional collecting and considerable attention to the differences in vegetational cover, rock composition, and sun exposure for each of the individual colonies. At present, it is only possible to call attention to some of the variation observed.

The name *osmondi* is taken from the location of this species in the drainage of Osmond Creek, a tributary of the Ord River.

Genus *Ordtrachia* Solem, 1984

Ordtrachia is a limestone associated genus previously (Solem, 1984: 647-670) known from four species ranging along the east shore of Lake Argyle. The recorded colonies extend from a few kilometres east of Rosewood station and The Rock Wall, which is southeast of Rosewood Station (Solem, 1984, 692, fig. 179), south along the Duncan Highway to Station WA-709, located 37.2 km north of the Nicholson River. The available records were obtained during hasty trips over the Duncan Highway. Time did not permit extensive east or west investigations. Numerous lateral extensions of ranges can be anticipated, together with probable collection of new species. Some additional material found by Vince Kessner awaits detailed study, including a new species from the Palms Yard area.

The species described below, *Ordtrachia elegans*, provides a very significant northward range extension. It shares rock space with the southeasternmost record of the Ningbing-Jeremiah Hills endemic genus *Cristilabrum*.

Ordtrachia elegans, new species (Plates 1c-d, 3a-b; Figs 12-14, 18-19)

Comparative remarks

Ordtrachia elegans, from an isolated limestone ridge 7 km east of the Jeremiah Hills and about 8.5 km slightly southsouthwest of Point Spring, Weaber Ranges, is of average size (mean diameter 13.20 mm), with protruded keel (Fig. 13), comparatively widely open umbilicus (Fig. 14), no radial ribs present, and dense pustulations (Plate 1c-d) on both spire and shell base. The radially ribbed *O. intermedia* Solem (1984: 660, pl. 56d-f, 667, figs 172a-c) is more widely umbilicated, but has similar microsculpture. The very large (mean diameter 17.03 mm), smooth surfaced *O. grandis* Solem (1984: 660, pl. 56a-c, 663, figs a-c), also is much more depressed in shape (mean H/D ratio 0.434). *O. septentrionalis* Solem (1984: 651, pl. 54, 652, figs 166a-c), the previously northernmost known species, has a nearly closed umbilicus, only a weak trace of a keel, and less prominent micro-sculpture. *O. australis* Solem (1984: 652, figs 166d-f, 657, pl. 55a-d) is most similar in size and shape, but has a higher spire, narrower umbilicus (mean D/U ratio 10.4), and is larger (mean diameter 14.32 mm) in size. Anatomically (Figs 18-19), the extremely short vagina (V) and thickened base of the spermatheca (S) are most similar to those of *O. septentrionalis* Solem (1984: 653, fig. a) and very different from these structures in the other species (Solem, 1984: 658, figs 168a-b, 661, figs 169a-c, 668, figs 173a-b). The penis of *O. elegans* (Fig. 19) is short, somewhat longer than its sheath, and has the glandular outpocket barely visible compared with the other species.

Holotype

WAM 145.84, Station WA-987, isolated limestone ridge about 7 km east of Jeremiah Hills, and 8.5 km south-southwest of Point Spring, Weaber Ranges, north of Kununurra, Kimberley, Western Australia. 15° 25′ 31″ S, 128° 48′ 13″ E. Carlton 1:100,000 map sheet 4667 — 790:947m. Collected May 23, 1984 by Alan Solem, Laurie Price, and Ken Emberton. Height of shell 6.45 mm, diameter 13.05 mm, H/D ratio 0.494, whorls 5⅛, umbilical width 1.65 mm, D/U ratio 7.91.

Paratopotypes

WAM 146.84, WAM 147.84, FMNH 211733-4, 6 LA, 32 DA, 2 LJ, 13 DJ from the type locality.

Range

The single isolated ridge from which *Ordtrachia elegans* has been collected is about 0.7 km long and an estimated 0.32 km² in area. It is located east of the Jeremiah Hills and west of Point Spring, Weaber Ranges, north of Kununurra. A few unsampled, much smaller, scattered limestone outcrops lie between the type locality and the Jeremiah Hills. It is possible that they may contain some additional colonies.

Diagnosis

Shell average in size,11.95-14.75 mm (mean 13.20 mm) in diameter, with 4⅞+ to 5½ (mean 5⅛+) rather tightly coiled whorls. Apex and spire moderately elevated, slightly rounded above, height of shell 5.8-7.75 mm (mean 6.70 mm), H/D ratio 0.454-0.571 (mean 0.509). Apical sculpture (Plate 1c) of vague radial ridglets, postapical sculpture of prominent pustulations (Plate 1c) that become larger and more complex on lower spire (Plate 1d) and body whorl, but somewhat reduced on shell base. Shell periphery (Fig. 13) with protruded, thread-like keel. Body whorl slightly to moderately descending behind lip, which is broadly expanded and reflected, basal section often with a low node, lip partly reflected over umbilicus (Figs 12-14). Umbilicus moderately open (Fig. 14), width 1.05-2.25 mm (mean 1.60 mm), D/U ratio 5.81-12.4 (mean 8.52). Shell without colour bands, keel white, base lighter in tone. Based on 39 measured adults.

Genitalia (Figs 18-19) with extremely short vagina (V), relatively long free oviduct (UV) that enters vaginal-spermathecal channel at right angle, base of spermatheca (S) very thickened. Vas deferens (VD) entering relatively thin-walled penis sheath (PS) above middle, reflexing apically at attachment point of penial retractor muscle (PR) to enter epiphallus (E), which is greatly swollen and with accessory tissue. Prominence of glandular pocket at penis-epiphallic junction reduced. Penis (P) with lower portion showing vague pilasters. Central and lateral teeth of radula (Plate 3a) typical, transition between laterals and marginals abrupt (Plate 3b).

Discussion

Ordtrachia elegans is very similar in anatomy and shell sculpture to *O. septentrionalis*, but the shorter penis, very prominent keel on the shell periphery, and more open umbilicus of the former easily distinguish the two species.

The name *elegans* was suggested by Laurie Price, who collected most of the type series. They were deeper in talus than examples of the two *Cristilabrum* species living on the same slopes, and were found in a limited area. I thus honour his request as to the name for this beautiful little species.

Genus *Ningbingia* Solem, 1981

The basic systematic review and species descriptions of the six species of *Ningbingia* were presented by Solem (1981b: 326-358; 1985b: 943-947). More detailed discussion of local variation patterns will be presented elsewhere by Solem & Hayek (In preparation).

The subspecies described below, *Ningbingia australis elongata*, represents the southernmost record for the genus. Station WA-668, a small isolated hill occupying about 0.01 km², is located on the south bank of an unnamed creek that drains part of the east face of the North Ningbing Ranges.

Ningbingia australis elongata, new subspecies (Plate 1e; Figures 15-17, 20)

Comparative remarks

Ningbingia australis elongata, new subspecies, is an anatomically characterized subspecies. Shell size and shape of the two subspecies (Table 1) are essentially identical, except that the new subspecies has a slightly lower adult whorl count, and most specimens show no trace of body whorl angulation (compare Fig. 16 with Solem, 1981b: 339, fig. 77d). *N. a. elongata* (Fig. 20) has a shorter, thicker vagina (V), and the penis (P) is noticably longer than in *N. a. australis* (Solem, 1981b: 357, fig. 87). The only other species apt to be confused, is *N. bulla* Solem (1981b: 335-336, figs 74a-f, 75a-f, 342-344, figs 79-81), but it has a much shorter penis and the corrugated pilaster zone is restricted to the lower part of the penis chamber.

Holotype

WAM 148.84, Station 668, small isolated hill on south bank of unnamed creek, 2.9 road km north of Tanmurra Creek crossing, southeast of North Ningbing Ranges tip, north of Kununurra, East Kimberley, Western Australia, Australia. 15° 02′ 04″ S, 128° 36′ 17″ E. Carlton 1:100,000 map sheet 4667 — 575:378m. Collected 26 May 1980 by Alan Solem, Laurie Price, Fred and Jan Aslin. Height of shell 12.0 mm, diameter 18.5 mm, H/D ratio 0.647, whorls 5⅜-, umbilical width 3.0 mm, D/U ratio 6.18.

Paratopotypes

WAM 149.84, WAM 150.84, FMNH 205092-3, 14 LA, 119 DA, 12 LJ, 1O DJ from the type locality.

Range

The single known locality of *Ningbingia australis elongata* is a hillock less than 100 m in diameter and perhaps 20 m high, located about 650 m north of hills with *Turgenitubulus christenseni* Solem, 1981 (WA-706) and about 1,200 m southeast of the nearest known locality of *N. a. australis* (WA-998, on an outlier of the North Ningbing Ranges). Its total range is thus about 0.01 km².

Diagnosis

Shell 16.3-20.4 mm (mean 18.15 mm) in diameter, with 5- to 5½+ (mean 5 1/8+) normally coiled whorls. Apex and spire moderately and evenly elevated, height of shell 10.15-13.0 mm (mean 11.55 mm), H/D ratio 0.580-0.709 (mean 0.644). Apical sculpture of short, irregular ridglets, spire sculpture very weak (Plate 1e). Shell periphery normally rounded (Fig. 16), rarely angulated. Body whorl only

slightly descending behind lip, which is broadly expanded (Figs 15-17). Umbilicus only partly covered by reflected lip, open, width 2.9-3.95 mm (mean 3.2 mm), D/U ratio 4.15-6.47 (mean 5.43).

Terminal genitalia (Fig. 20) agreeing with nominate subspecies except for following features: vagina (V) shorter and thicker; the penis (P) is much longer and tightly kinked within the penis sheath (PS); corrugated pilasters (PP) lower and do not extend as far down the penis chamber. Radular teeth without unusual features, not illustrated.

Discussion

Initial study of this material suggested that it was typical of *Ningbingia australis*. Only after dissection of several populations was it realized that there were consistent differences in the length of the penis and the vagina, and also in the extent of corrugated pilaster area within the penis chamber. Actually, the illustrated example had the shortest of the three penes examined from WA-668. It was selected because the dissection of the upper chamber was the best for showing ridge detail. Because of the extensive kinking and coiling of the penis within the sheath, it is not possible to measure actual length with any degree of accuracy for either subspecies. Thus the rather unsatisfactory statement "much longer" has to suffice as a descriptor.

The minor differences in body whorl contour and whorl count are less than those associated with species level changes in other *Ningbingia*. The lengthening of the penis, but retention of the same pilaster structure, also is less than the species level differences. All of these minor differences are of the same general type found to indicate species level shifts in the Ningbing radiations, but the differences are not as great. Since the several dissected populations of *N. australis australis* agree closely with each other in regard to these features, the use of subspecific status is chosen to recognize the geographic variant. Unfortunately, no electrophoretic material was available for this subspecies. We passed within 50 m of the type locality in 1984, but did not stop to collect since it was then assumed to be typical *australis*.

The unnamed hill is deeply fissured at several spots and also has good accumulation of talus. Hence the populations of *Ningbingia australis elongata* are undoubtedly large in size.

The name *elongata* refers to its oversized penis.

Genus *Cristilabrum* Solem, 1981

Previous reports on the genus *Cristilabrum* (Solem, 1981b: 382-417; 1985b: 959-975) have described 11 species, one of which, *C. funium* Solem (1981b: 416-417, figs 100d-f) from the Roper River, Gulf of Carpenteria, is misclassified. This species will be reallocated elsewhere. Eight of these species share a basic pattern of genital structure. Two of them, *C. bilarnium* Solem (1981b: 411-416, pl. 18c, figs 100a-c, 106a-b) and *C. spectaculum* Solem (1985b: 966-972, figs 253a-c, 245a-b, 255a-d), have structures at least partly transitional to those characterizing the third restricted endemic Ningbing camaenid genus, *Turgenitubulus* Solem (1981b: 358-382; 1985b: 947-959). This situation suggests that the latter, which is characterized by a nearly unique genital pattern, is derived from the *Cristilabrum* stock.

One species, *Cristilabrum rectum* from an isolated ridge (WA-1005) lying north of The Gorge and west of the known range of *C. solitudum* Solem (1981b: 386-396, pl. 17a, figs 97a-c, 101a-b), is described as new. It also suggests transitional states between *Cristilabrum* and *Turgenitubulus*. A second probably new species, from isolated ridges west of the South Ningbing Ranges (WA-1032-1033), is represented by limited material. It shows features that, in other species of *Cristilabrum*, are indicative of species differences. Formal naming is withheld until adequate collections are available for study.

Cristilabrum rectum, new species (Plates 1f, 3c-d; Figs 21-23, 26-27)

Comparative remarks

Cristilabrum rectum, new species, is almost identical in shell features with *C. solitudum* Solem (1981b: 386-396, pl. 17a, figs 97a-c, 101a-b), differing in having a slightly wider umbilicus and

increased whorl count. The lip node in both species is reduced to a weak swelling (Fig. 22; Solem, 1981b: 391, fig. 97b), which contrasts with the prominent nodes in most other taxa from the South Ningbing Ranges. Anatomically, *C. rectum* (Figs 26-27) is immediately recognizable in having a very short penis (P) which is scarcely longer than the vagina (V), with thick walls and a relatively large set of internal pilasters. The vas deferens (VD) enters the penis sheath (PS) noticably above the peni-oviducal angle and the spermatheca (S) is very large. In all of the other Central (*solitudum*) and South (*simplex, buryillum, monodon, primum, grossum, bubulum*) Ningbing Ranges species (Solem, 1981b: 400-410, figs 101-105; Solem, 1985b: 960-974, figs 249-250, 252), and the southern species *C. isolatum* (Solem, 1985b: 972-975, fig. 256), the penis is much larger in size and the vas deferens enters the sheath just above the peni-oviducal angle. Both *C. bilarnium* Solem (1981b: 477-476, figs 100a-c, 106a-b) and *C. spectaculum* Solem (1985b: 966-972, figs 254a-b, 255a-d) from the Jeremiah Hills and eastern isolated limestone hillocks have drastically altered penis structures and shells with heavy radial sculpture.

Holotype

WAM 151.84, Station WA-1005, isolated limestone ridge north of The Gorge and southwest of the south end of Central Ningbing Ranges north of Kununurra, East Kimberley, Western Australia, Australia. 15° 09′ 21″ S, 128° 37′ 56″ E. Carlton 1:100,000 map sheet 4667 — 604:243m. Collected 25 May 1984 by Alan Solem, Laurie Price, and Ken Emberton. Height of shell 11.8 mm, diameter 19.2 mm, H/D ratio 0.615, whorls 5 ⅞-, umbilical width 2.5 mm, D/U ratio 7.68.

Paratopotypes

WAM 152.84, WAM 153.84, WAM 160.84, FMNH 211791-2, FMNH 211794, 12 LA, 109 DA, 3 LJ, 10 DJ from the type locality.

Range

The single known locality (WA-1005) is a narrow limestone ridge, approximately 1.2 km long, whose total area is about 0.29 km². It lies south and west of the range of *C. solitudum*, just off the south tip of the Central Ningbing Ranges and north of The Gorge, East Kimberley, Western Australia.

Diagnosis

Shell relatively large, adult diameter 17.8-21.0 mm (mean 19.22 mm), with 5⅛- to 6⅜+ (mean 5⅞+) rather tightly coiled whorls. Apex and spire strongly elevated, sometimes slightly rounded above, height of shell 10.2-13.2 mm (mean 11.78 mm), H/D ratio 0.528-0.726 (mean 0.613). Apical sculpture weak (Plate 1f), spire and body whorl with at most very weak and irregular radial growth ridglets. Shell base smooth. Periphery (Fig. 22) rounded to slightly angulated in smaller individuals. Body whorl at most descending slightly behind lip, which is broadly expanded and reflected (Figs 21-23). Generally there is a very weak node on basal lip at columellar angle (Fig. 22). Umbilicus (Fig. 23) partly narrowed by reflexion of columellar lip, width 1.6-3.4 mm (mean 2.69 mm), D/U ratio 5.67-11.4 (mean 7.27). Shell pale horn in colour, base lighter in tone, lip white. Based on 122 measured adults.

Genitalia (Figs 26-27) with few features atypical of *Cristilabrum*, noticably shortening of the penis complex (P, Fig. 26) and vagina (V), plus higher entrance of vas deferens (VD) into penis sheath. Free oviduct (UV) long and curved, spermatheca (S) elongated. Vagina (V) short, slender. Vas deferens (VD) with neither ascending nor descending arm swollen, entering penis sheath noticably above peni-oviducal angle, free of sheath wall internally, reflexing apically at attachment of penial retractor muscle (PR). Penis (P, Fig. 27) also very short, longer than sheath (PS), thick-walled, internally with longitudinal pilasters, small cluster of pilasters around epiphallic pore (DP). Central and early lateral teeth typical (Plate 3d), cusp shaft angle high, tip sharp and only very slightly curved.

Discussion

Cristilabrum rectum (Fig. 26) and *C. solitudum* Solem (1981b:400, fig. 101) differ from the remaining main mass *Cristilabrum* in having the vagina and penis noticably shortened and the spermatheca much longer. The process has been carried much further in *rectum*. Whereas the penis complex is nearly 20 mm long in the genotype, *C. primum* Solem (1981b: 404, fig. 103a-b), and the coiled penis is closer to 30 mm in length, the penis sheath length is about 6.25 mm

in *solitudum*, with the penis only slightly longer than the sheath. The penis complex is reduced to a mere 4 mm long in *rectum* (Fig. 26), although the penis is longer than the sheath (Fig. 26), and the spermatheca (S, Fig. 26) is elongated, especially when contrasted with the main mass species, where it is reduced to a stub. The sheath length of 10 mm in *Cristilabrum* species, with a very long penis (P) coiled within the sheath (PS), and the very short spermatheca (S) provide a clear contrast (Fig. 28). The degree of radular tooth wear occurring in limestone rock dwellers (Plate 3c) provides a striking contrast to the structure of unworn teeth from the middle of the same radula (Plate 3d).

Cristilabrum rectum carries further anatomical trends that are seen first in *C. solitudum*. These species can be viewed as possible progenitors of *Turgenitubulus* in the shortening of the penis, rise in insertion of the vas deferens into the penis sheath, and development of pilasters around the epiphallic pore (DP). The changes in anatomy from *solitudum* to *rectum* are greater than those seen between adjacent species of *Cristilabrum* that show significant shell differences. Hence species level difference is proposed despite the very minor shell differences.

Collections of *Cristilabrum rectum* were made from three points along the west-northwest face of the type ridge, but were accidentally combined in the field by an assistant. The more sheltered exposure from direct solar insolation of these populations may explain why there is no difference in size (Table 3) between living and dead adults, whereas for most of the species collected in 1984 and 1986, living examples were significantly larger (Table 3).

The name *rectum*, from the latin for integrity or virtue, was chosen in recognition of the fact that this taxon provides the best morphological evidence for actual close relationships between *Cristilabrum* and *Turgenitubulus*.

Cristilabrum, probably new species (Figs 24-25, 28)

Comparative remarks

Stations WA-1032-1033 lie west of the known range for *Cristilabrum monodon* Solem (1985b: 959-965, figs 251a-c, 252a-c) and a little northeast of the known range of *C. bubulum* Solem (1981b: 408-410, figs 99d-f, 105a-b). The three species are almost identical in size and shape parameters (Table 1), except for the slightly narrower umbilicus (Fig. 25) of the probable new species. *C. bubulum* has the shell base with prominent radial sculpture and two apertural ridges; *C. monodon* has the shell base smooth and the one apertural ridge generally is wider and lower; *C.* probably new species has the smooth shell base of *monodon*, a high, more sharply defined basal lip node (Fig. 24) and sometimes a developed columellar-basal ridge that is less prominent than in *bubulum*. Anatomically, *C.* probably new species (Fig. 28) has a short, quite thick vagina (V), extremely short spermatheca (S), and a long, very slender penis (P) that is tightly coiled inside the upper part of the penis sheath (PS). *C. bubulum* Solem (1981b: 410, figs 105a-b) has the vagina long and slender, the spermatheca longer, and the penis only moderately longer than the penis sheath. *C. monodon* Solem (1985b: 964, figs 252a-c) has an extremely long vagina, elongated spermatheca, and a slender penis that is only moderately longer than the penis sheath. Both *C. primum* and *C. grossum* (Solem, 1981b: 404-405, figs 103-104) share the very short spermatheca present in *C.* probably new species, but differ in other genital features.

Material studied

South Ningbing Ranges: Sta. WA-1032, area of isolated limestone domed rocks about 3.5 km southwest of Ningbing Bore (15° 15′ 24″ S, 128° 39′ 36″ E, Carlton 1:100,000 map sheet 4667 — ca 640:130m) (7 DA, 7 DJ, WAM 156.84, FMNH 211874); Sta. WA-1033, high limestone pillars southwest of Ningbing Bore (15° 15′ 31″ S, 128° 39′ 50″ E, Carlton 1:100,000 map sheet 4067 — ca 638:129m) (6 LA, 10 DA, WAM 154.84, WAM 155.84, FMNH 211875-7).

Range

The two stations are on opposite sides of a small valley in the South Ningbing Ranges, located about 2 km north of the range of *C. grossum* and 700 m due west of the limestone masses inhabitated by *C. monodon*. Ningbing Bore lies about 3.5 km north-northeast.

Discussion

The shell and anatomical differences outlined above are the kind of differences found between sympatric congeners elsewhere in the Ningbing Ranges. The shell differences are larger than those separating *C. bilarnium* and *C. spectaculum* (see Solem, 1985b: 965-972), species that are very different in genital anatomy, while the anatomical changes are fully equivalent to the differences found between neighbouring allopatric species of *Cristilabrum* along tne main mass of the Ningbing Ranges.

Despite this, nomenclatural recognition is withheld at this time. Very limited material, only 24 adult specimens, were available for study. Although two of the living specimens were prepared for electrophoretic analysis, the vials containing these were among the 50% of *Cristilabrum* examples that lost their labels while in liquid nitrogen. Thus no allozyme data was available for comparison with the similar species. This area of the Ningbing Ranges still needs intensive collecting. Description of this taxon is withheld pending the availability of specimens from several additional localities.

No shell differences were noted between the two populations sampled (Table 3).

Genus *Mesodontrachia* Solem, 1985

The only previously known species, *Mesodontrachia desmonda* Solem (1985b: 867-869, pl. 87a-f, figs 218a-c, 219a-c) from near Desmonds Passage, West Baines River, and *M. fitzroyana* Solem (1985b: 870-875, pl. 88a-f, figs 220a-c, 221a-c) from 24.4 km east of Timber Creek Police Station, Victoria Highway, were from the Northern Territory. Discovery of a third species in the Cockburn Range, southwest of Wyndham, East Kimberley, Western Australia represents a westward range extention of about 200 km.

Mesodontrachia cockburnensis, new species, has very light subsutural and supraperipheral red spiral colour bands, is slightly more depressed, and noticably more widely umbilicated than either of the above species. The shell shows the characteristic *Mesodontrachia* microsculpture (compare Plate 2a-b with Solem, 1985b: 864-865, pls 87a-b, 88d), which obviously differs from that seen in *Amplirhagda* (Plate 1a-b), *Ningbingia* (Plate 1e), and *Cristilabrum* (Plate 1f).

The drainages of the lower Pentecost and Chamberlain Rivers are inhabited by *Amplirhagada questroana* Solem, 1981 and *Prymnbriareus nimberlinus* Solem, 1981, so I was anticipating that a probable relative of either genus would be in the Cockburn Ranges. It was quite surprising, upon dissection, to discover that this was a significant range extention of the Northern Territory genus *Mesodontrachia*. Its easternmost species, *M. fitzroyana*, lives in barely exposed limestone outcrops scattered along several km of the Victoria Highway east of Timber Creek Police Station (additional records courtesy of Vince Kessner); *M. desmonda* has been found only in massive sandstone cliffs by Upper Saddle Creek, about 8 km west of Desmond's Passage, living in deep fissures and under large boulders; and *M. cockburnensis* occurs in deep mixed rock talus in the Cockburn Range of Western Australia. These diverse records suggest that additional species of *Mesodontrachia* await discovery throughout this area.

Mesodontrachia cockburnensis, new species (Plates 2a-b, 3e-f; Figs 29-34)

Comparative remarks

Mesodontrachia cockburnensis, new species (Figs 29-31) from the Cockburn Ranges, southwest of Wyndham, East Kimberley, Western Australia differs from *M. desmonda* Solem, 1985 and *M. fitzroyana* Solem, 1985 in having two spiral red colour bands, a wider umbilicus, and less elevated apex. The radial microsculpture (Plate 2a-b), very narrow, simple lip, and absence of any lip nodes immediately separate it from any of the neighbouring camaenids. Anatomically, the terminal genitalia (Figs 32-34) are elongated compared with those of its congeners (Solem, 1985b: 869, figs 219a-e, 872, figs 221a-c), the prominent fibers binding the vas deferens to the penis sheath in the other two species are lacking, and the vas deferens enters the penis sheath slightly above the middle rather than near apically. The penis is much longer than its sheath, with coiling of the penis occurring in the lower half of the sheath, a very unusual situation in the Australian camaenids.

Holotype

WAM 157.84, Station WA-988, talus slope on southwest face of Cockburn Range, above Pentecost River, south-southwest of Wyndham, East Kimberley, Western Australia, Australia. 15° 54′ 25″ S, 128° 01′ 42″ E. Cambridge Gulf 1:250,000 map sheet SD52-14 — 637:991yds. Collected 24 May 1984 by Alan Solem, Laurie Price, and Ken Emberton. Height of shell 12.1 mm, diameter 20.45 mm, H/D ratio 0.592, whorls 5½+, umbilical width 2.4 mm, D/U ratio 8.52.

Paratopotypes

WAM 158.84, WAM 159.84, FMNH 211736-7, 2 LA, 55 DA, 6 L;, 63 DJ from the type locality.

Range

The type locality is a massive, shaded rock slide on the upper slopes of a southwest facing valley in the Cockburn Ranges, near Wyndham. Undoubtedly other colonies of this species will be found in similar situations in the Cockburn Ranges.

Diagnosis

Shell of average size, adult diameter 18.45-22.45 mm (mean 20.30 mm), with 5⅛ to 5⅞- (mean 5½) normally coiled whorls. Apex and spire modestly and evenly elevated, height of shell 10.3-13.25 mm (mean 11.58 mm), H/D ratio 0.497-0.632 (mean 0.571). Apical and early spire sculpture typical (Plate 2a-b), reduced on lower spire and body whorl, shell base with irregular growth lines only. Shell periphery (Fig. 30) rounded. Body whorl not descending behind lip, which is reflected, but only narrowly expanded (Figs 29-31). No trace of a basal node or knob. Umbilicus (Fig. 31) slightly narrowed by reflexion of columellar lip, moderately open, width 1.15-3.55 mm (mean 2.45 mm), D/U ratio 5.59-17.6 (mean 8.52). Shell light greenish yellow horn in tone, weak red spiral subsutural and supraperipheral colour bands visible in fresh or live examples, base lighter, lip white. Based on 58 measured adults.

Genitalia (Figs 32-34) with terminalia elongated, pallial and apical portions typical. Ovotestis (G) in inactive phase, hermaphrodictic duct (GD), talon (GT), albumen gland (GG), prostate (DG), and uterus (UT) normal. Free oviduct (UV) short, not kinked. Spermatheca (S) with head bound by fibers to base of prostate-uterus, shaft gradually merging with free oviduct to form vagina (V), which is long and slender, internally with nearly smooth walls. Vas deferens (VD) slender, entering penis sheath (PS) about midpoint (Figs 32-34), passing to apex of sheath, where it reflexes at insertion point of penial retractor muscle (PR), expanding slightly into a probable epiphallic section (E). Penis sheath (PS) thin-walled above, somewhat thicker on lower portions. Penis proper (P) beginning slightly above midpoint of sheath, tightly coiled in lower section of sheath (Fig. 33). Fibers bind the penis-epiphallic junction to the sheath wall. Interior of penis (Fig. 34) with crowded, somewhat indistinct longitudinal pilasters. Central and lateral teeth (Plate 3e) with slightly blunted tip, moderate anterior flare, typical shaft angle and basal ridge. Transition between laterals and marginals typical.

Discussion

The elongation of terminal genitalia in *Mesodontrachia cockburnensis* is the fundamental difference from the other known species. Changes in the vas deferens insertion and penis position are secondary to the basic shift. Radular tooth structure (Plate 3e-f) agrees more with that of *M. fitzroyana* than *M. desmonda* (see Solem, 1985b: 864-865, pls 87-88).

Given the disparate number of specimens, there is no significant difference in size and shape between the live and dead specimens (Table 3).

The name *cockburnensis* refers to the range from which it was collected.

DISCUSSION

Most of these species were collected in the course of narrowly targeted field work. My 1984 field trip was designed to answer two questions: 1) to provide east-west delineation of ranges for species of the three Ningbing endemic genera, *Ningbingia, Turgenitubulus, Cristilabrum*, while collecting material of all Ningbing camaenid species for electrophoretic analysis; and 2) determine if unsampled hill areas to the west, southwest, and south of the Ningbing Ranges had any

representatives of the Ningbing genera, or if their camaenid fauna consisted solely of other faunal elements.

A few days of helicopter time permitted sampling limestone hillocks in and near the Ningbing Ranges that we had not been able to reach, or even see, during ground travel. *Ordtrachia elegans*, *Cristilabrum rectum*, and *C.* probably new species resulted from this activity. Collecting west of Cambridge Gulf (*Amplirhagada cambridgensis*) and in the Cockburn Range (*Mesodontrachia cockburnensis*) was productive, while stations along the Pentecost and Chamberlain Rivers extended the ranges of *Amplirhagada questroana* Solem, 1981 and *Prymnbriareus nimberlinus* Solem, 1981 (Solem, unpublished). A previously unrecognized subspecies, collected in 1980, from the Ningbing Ranges (*Ningbingia australis elongata*) and the considerable southeastern range extension for *Amplirhagada osmondi* complete the material reviewed above.

All specimens were collected in late May of 1980, 1984 or 1986 and thus the genitalia were in the inactive, early dry season phase, with shrunken ovotestis (G) and hermaproditic duct (GD). Previous published work on Ningbing taxa involved either late May or early November (very late dry season) collections, so that reproductive tract states are directly comparable.

These species permit making a few biogeographic comments. First and most obvious, much remains to be learned about the land snails of this region. Undoubtedly many additional species remain to be discovered. The changes in known generic ranges were substantial: *Amplirhagada* from the Drysdale River east to Cambridge Gulf, a shift of about 120 km, and then a southeastern extension from roughly the junction of the Pentecost and Chamberlain Rivers to Red Rock Creek in the upper Ord River drainage, a shift of perhaps 150 km; *Ordtrachia* north from Rosewood Station to near the Weaber Ranges, a change of more than 100km; and a westward extension of about 200 km for *Mesodontrachia*.

These same changes also suggest that the radiation of camaenids in the Ningbing Range, *Ningbingia-Turgenitubulus-Cristilabrum*, is of restricted endemics. Two West Kimberley taxa, *Amplirhagada* and *Xanthomelon*, occupy the west side of Cambridge Gulf; *Mesodontrachia* extends from hills southwest (Cockburn Ranges) and then east into the Northern Territory; and *Amplirhagada* is found south of Lake Argyle and in the Pentecost-Chamberlain Rivers area. The failure to find any species of the Ningbing genera extralimitally, does not mean that such do not exist, but does make it increasingly probable that these genera are an *in situ* radiation of restricted endemics. By demonstrating the presence of other camaenid genera in the neighbouring areas, the probability of finding the Ningbing taxa elsewhere is substantially lessened.

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TABLE 1. Range of Shell Variation

Taxon	Number of Adults Measured	Mean and Range of: Shell Height (in mm)	Shell Diameter (in mm)	H/D Ratio	Whorls	Umbilical Width (in mm)	D/U Ratio
Amplirhagada							
cambridgensis	7	13.80 (12.05-14.85)	19.99 (18.7-20.95)	0.689 (0.633-0.729)	5⅞- (5⅝--6⅛-)	1.11 (0.65-1.35)	19.1 (14.3-32)
osmondi	173	12.59 (8.3-15.65)	19.32 (14.2-22.5)	0.650 (0.557-0.758)	5¾+ (4⅞+-6⅜+)	1.28 (0.6-2.0)	15.7 (9.71-33)
Ordtrachia							
elegans	39	6.70 (5.8-7.75)	13.20 (11.95-14.75)	0.509 (0.454-0.571)	5⅛+ (4⅞+-5½)	1.60 (1.05-2.25)	8.52 (5.81-12.4)
Ningbingia							
a. australis Solem, 1981	390	11.70 (9.9-13.6)	18.12 (15.6-20.55)	0.647 (0.553-0.741)	5⅜- (4⅞-5⅞)	3.16 (1.4-4.2)	5.74 (4.41-12.9)
a. elongata	134	11.55 (10.15-13.0)	18.15 (16.3-20.4)	0.644 (0.580-0.709)	5⅛+ (5--5½+)	3.21 (2.9-3.95)	5.43 (4.15-6.47)
Cristilabrum							
rectum	122	11.78 (10.2-13.2)	19.22 (17.8-21.0)	0.613 (0.528-0.726)	5⅞+ (5⅛--6⅜+)	2.69 (1.6-3.4)	7.27 (5.67-11.4)
solitudum Solem, 1981	660	10.69 (7.95-12.7)	17.96 (15.95-20.75)	0.595 (0.495-0.718)	5⅝- (4⅛--6⅛+)	3.07 (1.55-4.05)	5.95 (4.65-11.3)
monodon Solem, 1985	480	8.89 (7.4-10.5)	17.37 (14.8-19.5)	0.512 (0.454-0.591)	5½- (5⅛--6+)	2.48 (1.1-3.6)	7.25 (4.70-16.6)
bubulum Solem, 1985	873	8.98 (6.7-11.45)	17.68 (14.7-21.2)	0.508 (0.420-0.615)	5½ (4⅞-6¼+)	2.28 (0.65-3.9)	8.10 (4.79-24.5)
new species	23	8.90 (7.4-10.2)	17.65 (16.2-18.6)	0.505 (0.454-0.564)	5⅝- (5⅛-5⅞)	1.69 (1.2-2.6)	10.8 (6.73-15.0)
Mesodontrachia							
cockburnensis	58	11.58 (10.3-13.25)	20.30 (18.45-22.75)	0.571 (0.497-0.632)	5½ (5⅛-5⅞-)	2.45 (1.15-3.55)	8.52 (5.59-17.6)

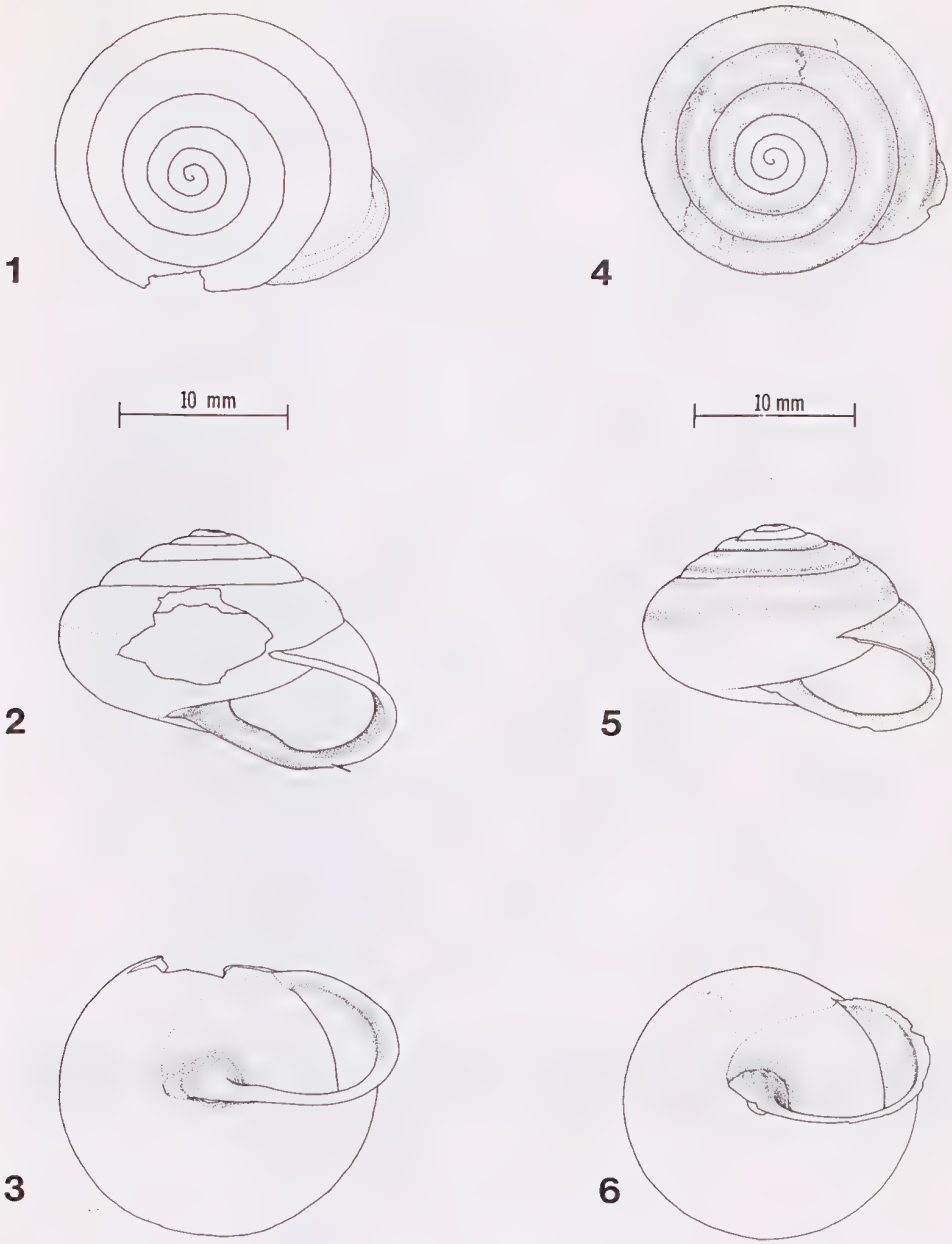
TABLE 2. Local Variation in *Amplirhagada osmondi* and *A. cambridgensis*

Taxon & Locality	Number of Adults Measured	Mean, SEM and Range of: Shell Height (in mm)	Shell Diameter (in mm)	H/D Ratio	Whorls	Umbilical Width (in mm)	D/U Ratio
A. cambridgensis							
WA-985, Lyne River, Cambridge Gulf,							
23-V-1984, FMNH 211718	1L	14.50	20.26	0.716	5⅞+	0.65	32
23-V-1984, FMNH 211719	7D	13.68 ± 0.402 (12.05-14.85)	19.95 ± 0.390 (18.7-20.95)	0.685 ± 0.013 (0.633-0.729)	5⅞+ (5½+-6+)	1.19 ± 0.055 (0.95-1.35)	17.0 ± 1.088 (14.3-22.4)
A. osmondi							
Palms Yard Outstation,							
25-V-1986, AM C.150366	10L	10.85 ± 0.168 (10.45-11.95)	17.14 ± 0.186 (16.15-18.1)	0.633 ± 0.007 (0.597-0.672)	5⅜+ (5¼--5½)	1.32 ± 0.057 (1.1-1.6)	13.1 ± 0.526 (10.5-15.9)
AM C.150366	10D	11.16 ± 0.172 (10.35-12.25)	17.04 ± 0.232 (15.75-18.0)	0.655 ± 0.007 (0.631-0.699)	5½- (5¼+-5⅝)	1.17 ± 0.090 (0.85-1.710)	15.4 ± 1.266 (9.71-21.7)
VK 9338	9D	10.98 ± 0.297 (8.8-11.8)	17.06 ± 0.387 (14.2-18.15)	0.643 ± 0.006 (0.619-0.680)	5⅝- (5⅛+-5⅞-)	1.05 ± 0.046 (0.9-1.25)	16.5 ± 0.725 (13.9-19.7)
FMNH 215266	2L	11.35 (10.8-11.9)	17.08 (16.15-18.0)	0.665 (0.661-0.668)	5½+ (5½-5⅝+)	1.46 (1.4-1.5)	11.7 (11.4-12.0)
3.3 km E of Palms Yard,							
25-V-1986, AM C.150361	1L	13.50	20.71	0.652	5¾+	1.08	19.2
AM C.150361	28D	13.66 ± 0.141 (12.3-15.2)	20.82 ± 0.140 (19.2-22.35)	0.636 ± 0.023 (0.603-0.743)	6- (5⅝+-6¼-)	1.39 ± 0.052 (0.95-2.0)	15.5 ± 0.585 (10.7-22.3)
VK 9339	7D	14.14 ± 0.752 (13.45-14.9)	20.55 ± 1.180 (17.75-22.05)	0.690 ± 0.210 (0.649-0.758)	6 (5¾+-6¼-)	1.33 ± 0.506 (0.85-1.6)	16.1 ± 2.045 (11.5-24.3)
6.2 km E of Palms Yard,							
26-V-1986, AM C.150379	5L	12.92 ± 0.401 (12.1-14.1)	19.05 ± 0.558 (17.3-20.55)	0.679 ± 0.015 (0.644-0.716)	5⅞ (5⅝+-6⅛-)	1.10 ± 0.102 (0.8-1.4)	17.9 ± 1.45 (14.7-21.5)
AM C.150379	25D	13.26 ± 0.148 (12.0-14.75)	20.26 ± 0.185 (18.65-21.85)	0.655 ± 0.006 (0.582-0.693)	5¾+ (5½-6¼-)	1.33 ± 0.056 (0.7-1.85)	15.9 ± 0.740 (11.1-25)

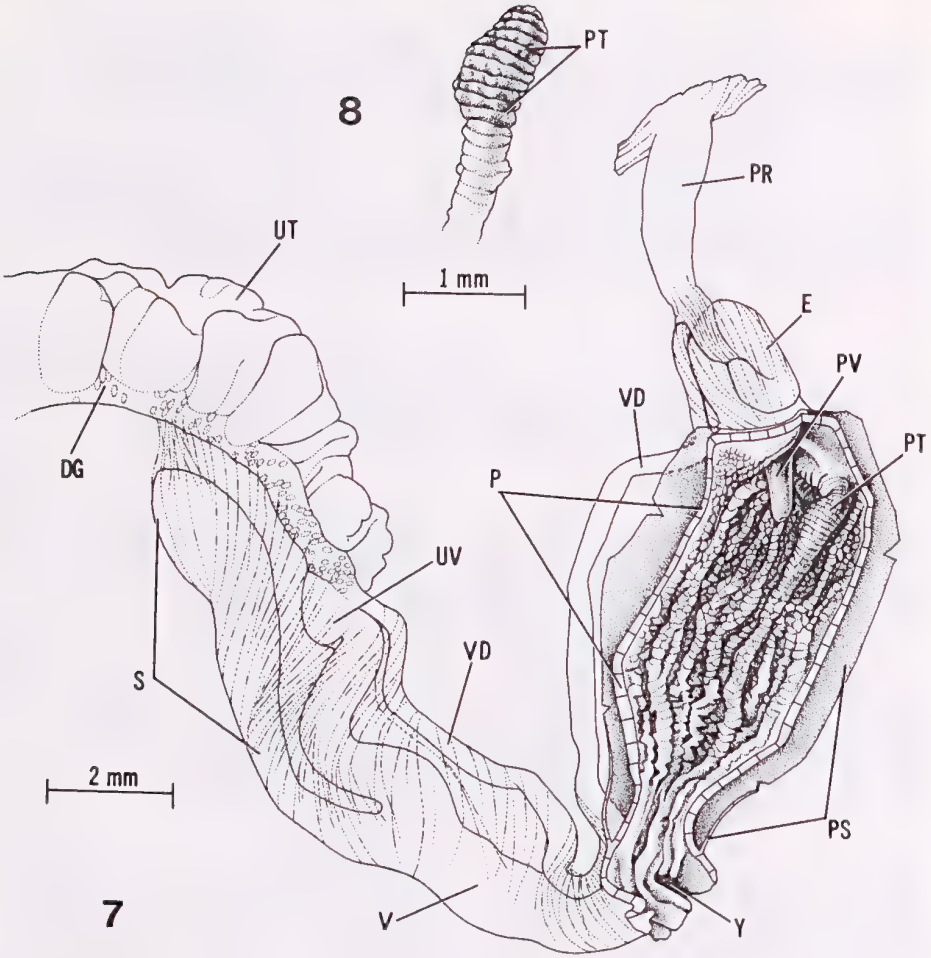
VK 9340	12D	13.29 ± 0.223 (11.85-14.3)	19.52 ± 0.205 (18.4-20.5)	0.681 ± 0.010 (0.631-0.754)	5⅞+ (5⅝+-6¼-)	1.22 ± 0.080 (0.9-1.85)	16.6 ± 0.911 (10.5-21.1)
VK	18D	12.99 ± 0.929 (11.05-14.2)	19.62 ± 0.959 (17.5-21.3)	0.662 ± 0.152 (0.621-0.701)	5⅞- (5½+-6⅛-)	1.20 ± 0.538 (0.6-1.85)	17.47 ± 1.220 (10.1-33)
8.9 km E of Palms Yard, 26-V-1986, AM C.150417	3D	11.80 ± 0.372 (11.05-12.2)	18.69 ± 0.578 (17.55-19.45)	0.631 ± 0.005 (0.624-0.640)	5¾- (5¾--5¾+)	1.43 ± 0.166 (1.1-1.7)	13.5 ± 2.044 (10.4-17.4)
19.4 km E of Palms Yard, 26-V-1986, VK 9341	8D	9.81 ± 0.319 (8.3-10.9)	16.61 ± 0.329 (14.9-17.85)	0.589 ± 0.009 (0.557-0.628)	5¼+ (4⅞+-5¾+)	1.27 ± 0.057 (1.05-1.45)	13.3 ± 0.675 (11.1-16.4)
30 km E of Palms Yard, 26-V-1986, VK 9343	2D	10.86 ± 0.160 (10.7-11.0)	18.61 ± 0.335 (18.3-18.95)	0.584 ± 0.019 (0.565-0.603)	5½+ (5½--5⅝+)	1.27 ± 0.290 (1.0-1.55)	15.4 ± 3.252 (12.1-18.7)
33.7 km E of Palms Yard, 26-V-1986, AM C.150373	2L	12.36 (12.3-12.4)	17.90 (16.7-19.1)	0.694 (.645-.743)	5¾+ (5⅝-5⅞+)	1.46 (1.3-1.6)	12.3 (11.8-12.8)
AM C.150373	5D	11.83 ± 0.546 (10.7-13.75)	18.78 ± 0.536 (17.55-20.5)	0.629-0.011 (0.609-0.671)	5⅝- (5⅜--5⅞-)	1.29 ± 0.118 (0.95-1.6)	15.0 ± 1.292 (11.7-18.3)
VK 9344	11D	11.93 ± 0.194 (11.25-13.35)	18.61 ± 0.222 (17.55-19.75)	0.641 ± 0.008 (0.608-0.681)	5⅝+ (5½+-6⅛-)	1.37 ± 0.074 (1.0-1.7)	13.9 ± 0.674 (11.4-17.8)
Bungle Bungle Outstation, 26-V-1986, AM C.150424	8D	13.49 ± 0.421 (11.85-15.65)	20.47 ± 0.405 (18.85-22.5)	0.659 ± 0.012 (0.597-0.706)	6 (5¾--6⅜+)	1.20 ± 0.068 (0.9-1.45)	17.4 ± 1.044 (13.1-22.3)
VK 9342	2D	12.85 ± 0.015 (12.85-12.85)	18.61 ± 0.315 (18.3-18.95)	0.690 ± 0.013 (0.678-0.703)	5¾- (5⅝+-5¾-)	0.97 ± 0.280 (0.7-1.25)	21.0 ± 6.397 (14.6-27.4)
2 km from Bungle Bungle turn-off, 27-V-1986, AM C.150425	6D	13.19 ± 0.120 (12.85-13.6)	20.08 ± 0.353 (18.45-21.0)	0.657 ± 0.010 (0.632-0.697)	5⅞- (5⅝+-5⅞+)	1.40 ± 0.137 (1.05-1.95)	15.0 ± 1.342 (10.5-19.3)
Spring Creek, 27-V-1986, AM C.150367	2L	13.40 (13.2-13.6)	20.00 (20.0-20.0)	0.671 (0.660-0.681)	5⅞+ (5⅞-6-)	1.14 (0.9-1.4)	18.4 (14.5-22.2)

TABLE 3. Local Variation in new species of *Ordtrachia, Ningbingia, Cristilabrum* and *Mesodontrachia*

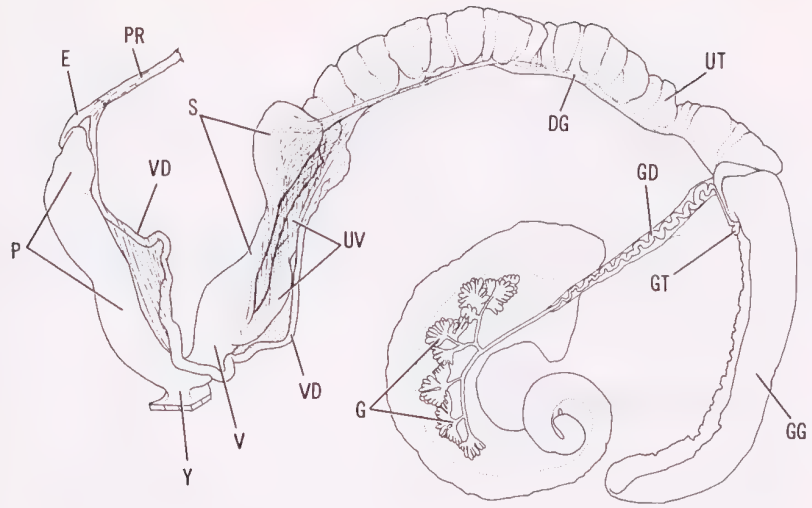
Taxon & Locality	Number of Adults Measured	Mean, SEM and Range of: Shell Height (in mm)	Shell Diameter (in mm)	H/D Ratio	Whorls	Umbilical Width (in mm)	D/U Ratio
Ordtrachia elegans							
WA-987, FMNH 211734	6L	6.97 ± 0.198 (6.4-7.75)	13.46 ± 0.105 (13.1-13.75)	0.517 ± 0.013 (0.487-0.571)	5¼- (5+-5½)	1.65 ± 0.095 (1.45-2.1)	8.34 ± 0.390 (6.51-9.21)
FMNH 211733	33D	6.66 ± 0.061 (5.8-7.3)	13.15 ± 0.094 (11.95-14.75)	0.507 ± 0.005 (0.454-0.570)	5⅛+ (4⅞+-5½-)	1.60 ± 0.055 (1.05-2.25)	8.56 ± 0.311 (5.81-12.4)
Ningbingia australis elongata							
WA-668, FMNH 205092	14L	12.11 ± 0.168 (11.0-13.0)	18.77 ± 0.212 (17.75-20.4)	0.646 ± 0.005 (0.611-0.678)	5¼+ (5+-5½+)	3.42 ± 0.039 (3.2-3.75)	5.49 ± 0.050 (5.19-5.78)
FMNH 205093	120D	11.48 ± 0.134 (10.15-12.95)	18.08 ± 0.050 (16.3-19.3)	0.644 ± 0.002 (0.580-0.709)	5⅛ (5--5½-)	3.19 ± 0.064 (2.9-3.95)	5.42 ± 0.030 (4.15-6.47)
Cristilabrum rectum							
WA-1005, FMNH 211791-2	12L	11.75 ± 0.164 (10.9-12.6)	19.28 ± 0.133 (18.4-19.9)	0.610 ± 0.009 (0.565-0.656)	5¾+ (5⅛--6⅛+)	2.67 ± 0.124 (2.2-3.3)	7.36 ± 0.269 (6.03-8.73)
FMNH 211794	110D	11.78 ± 0.062 (10.2-13.2)	19.21 ± 0.063 (17.8-21.0)	0.614 ± 0.003 (0.528-0.726)	5⅞+ (5½--6⅛+)	2.69 ± 0.034 (1.6-3.4)	7.27 ± 0.093 (5.67-11.4)
Cristilabrum new species							
WA-1033, FMNH 211876-7	6L	8.90 ± 0.139 (8.5-9.3)	17.73 ± 0.203 (17.1-18.6)	0.502 ± 0.010 (0.480-0.543)	5⅜- (5½-5⅝)	1.93 ± 0.189 (1.4-2.6)	9.73 ± 0.270 (6.73-13.3)
FMNH 211875	10D	9.01 ± 0.193 (8.1-10.2)	17.77 ± 0.175 (16.6-18.3)	0.507 ± 0.009 (0.453-0.564)	5⅜- (5⅜-5⅞)	1.70 ± 0.094 (1.2-2.1)	10.8 ± 0.653 (8.71-15.0)
WA-1032, FMNH 211874	7D	8.76 ± 0.246 (7.4-9.3)	17.41 ± 0.356 (16.2-18.6)	0.503 ± 0.012 (0.457-0.556)	5⅝ (5⅛-5⅞)	1.54 ± 0.053 (1.4-1.7)	11.4 ± 0.464 (10.1-13.3)
Mesodontrachia cockburnensis							
WA-988, FMNH 211736	2L	12.00 (11.8-12.2)	20.93 (20.15-21.7)	0.574 (0.562-0.586)	5⅜- (5¼-5⅛+)	2.35 (2.15-2.55)	8.94 (8.50-9.37)
FMNH 211737	56D	11.57 ± 0.086 (10.3-13.25)	20.28 ± 0.116 (18.47-22.75)	0.571 ± 0.004 (0.498-0.632)	5½ (5⅛-5⅞-)	2.47 ± 0.058 (1.15-3.55)	8.51 ± 0.240 (5.60-14.6)

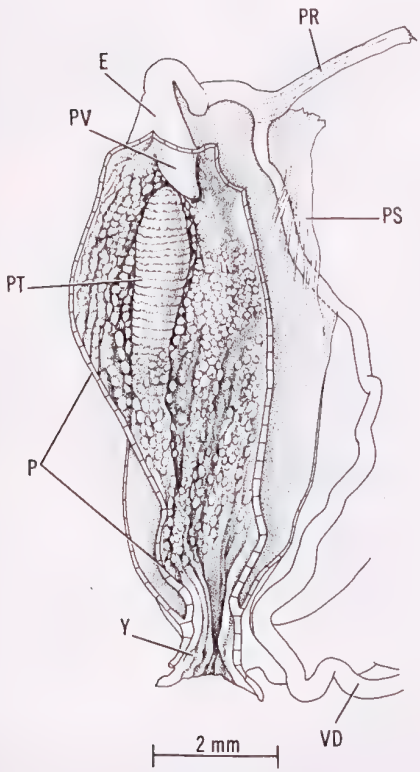


FIGURES 1-6. Shells of *Amplirhagada cambridgensis* and *A. osmondi*: 1-3, holotype of *Amplirhagada cambridgensis*, new species. WAM 142.84. WA-985, Lyne River basin, Cambridge Gulf; 4-6, holotype of *Amplirhagada osmondi*, new species. AM C.150373. PC-52, 33.7 km southeast of Palms Yard, near Red Rock Creek, southeast of Turkey Creek. Scale lines equal 10 mm.

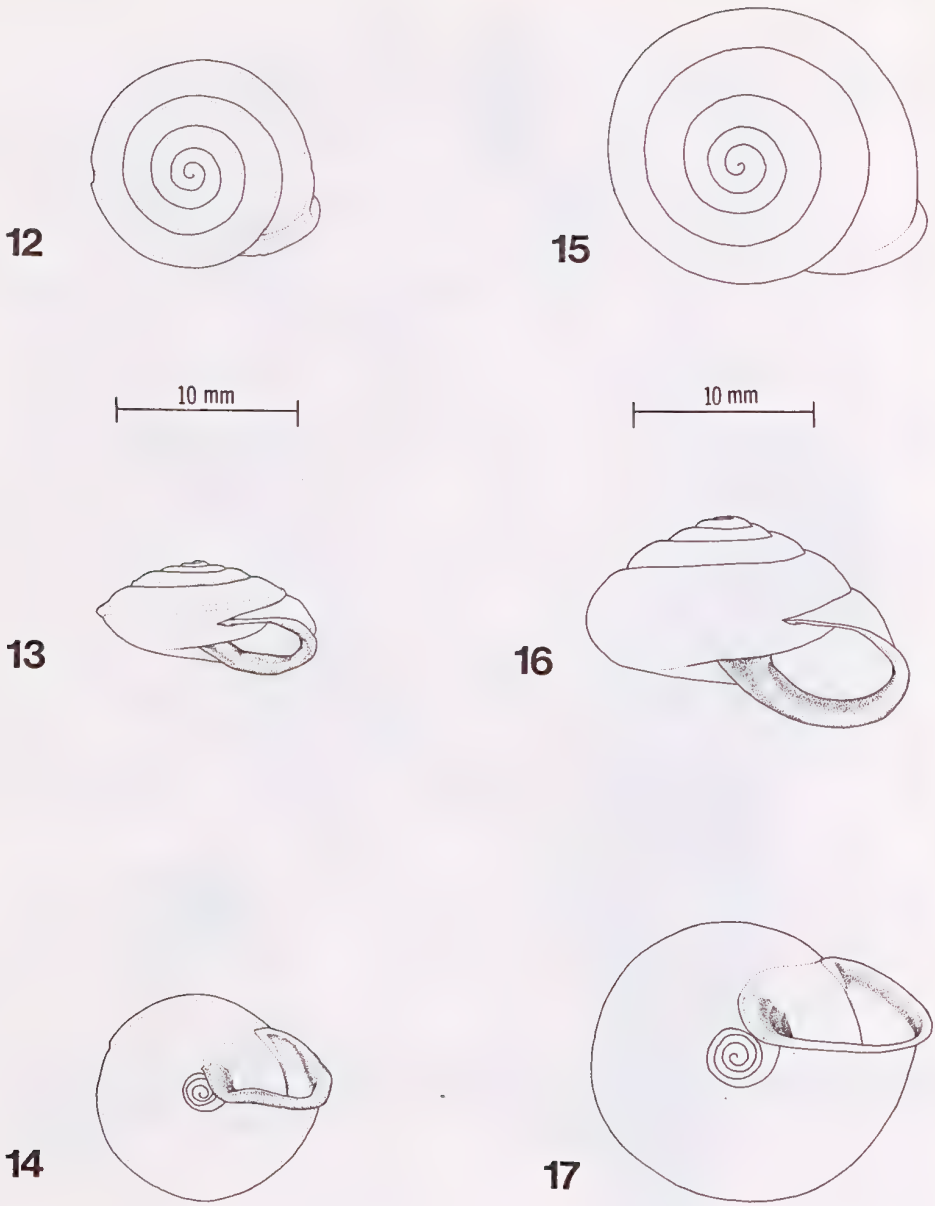


FIGURES 7-8. Genitalia of *Amplirhagada cambridgensis*, new species. FMNH 211718. WA-985, Lyne River basin, Cambridge Gulf. 23 May 1984: 7, interior of penis complex; 8, surface of principal pilaster. Scale lines as marked.

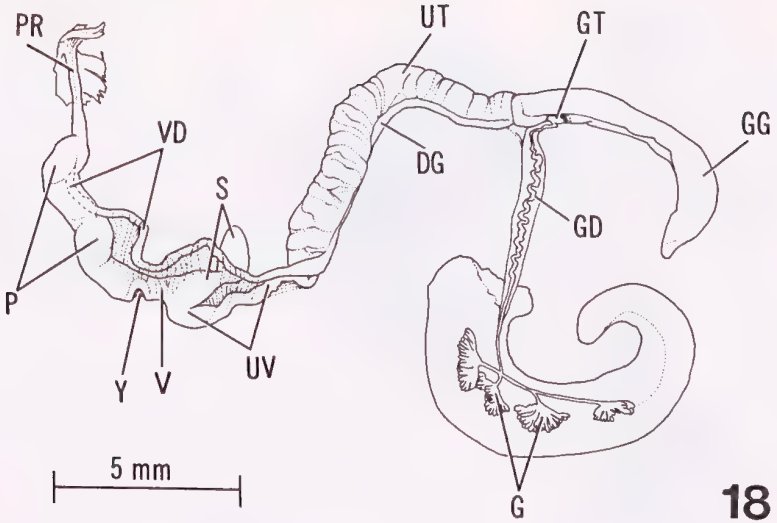


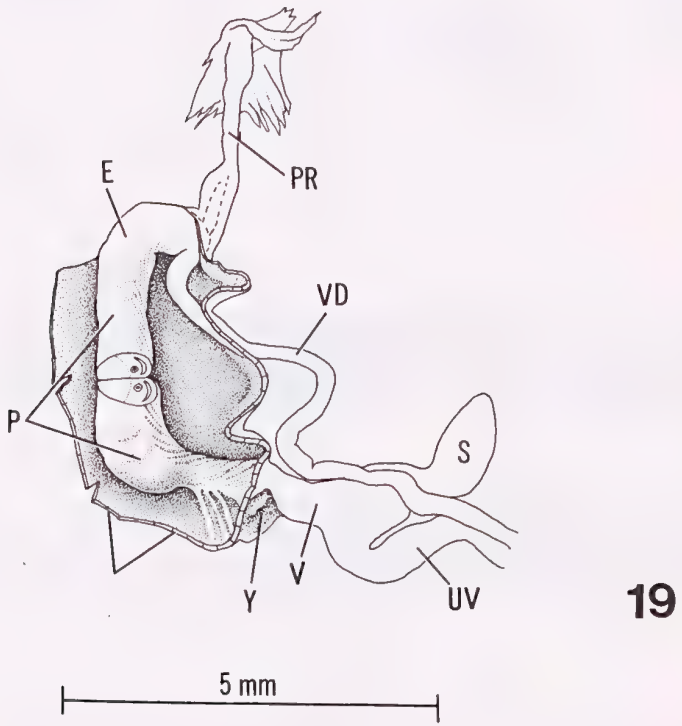


FIGURES 9-11. Genitalia of *Amplirhagada osmondi*, new species. FMNH 215266. Palms Yard, 37 km southeast of Turkey Creek. 25 May 1986: 9, whole genitalia; 10, interior of penis complex; 11, surface of principal pilaster. Scale lines as marked.



FIGURES 12-17. Shells of *Ordtrachia elegans* and *Ningbingia australis elongata*; 12-14, holotype of *Ordtrachia elegans*, new species. WAM 145.84. WA-987, southsouthwest of Point Spring, Weaber Ranges, east of Jeremiah Hills, north of Kununurra; 15-17, holotype of *Ningbingia australis elongata*, new subspecies. WAM 148.84. WA-668, isolated hill 2.9 km north of Tanmurra Creek, south tip of North Ningbing Ranges. Scale lines equal 10 mm.





FIGURES 18-19. Genitalia of *Ordtrachia elegans*, new species. FMNH 211734. WA-987, southsouthwest of Point Spring, Weaber Ranges, east of Jeremiah Hills, north of Kununurra. 23 May 1984: 18, whole genitalia; 19, details of penis complex. Scale line equals 5 mm.

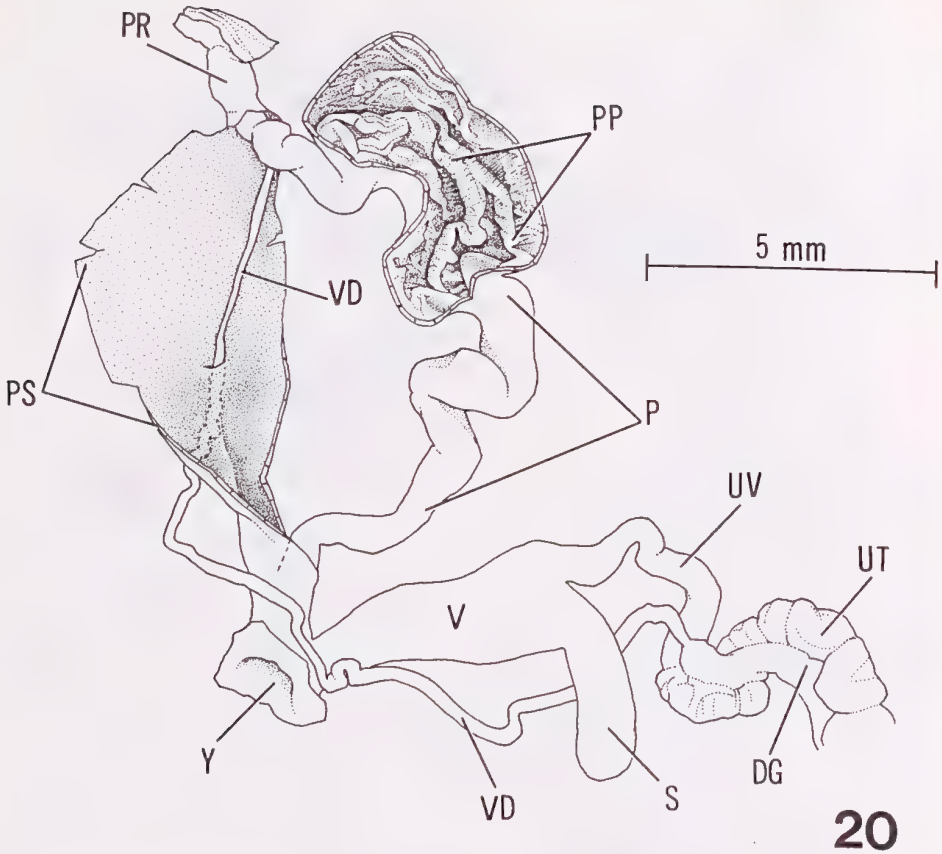
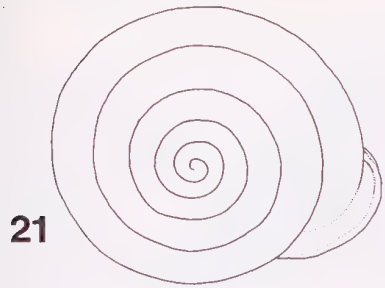
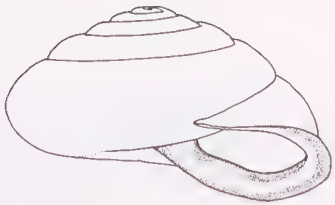
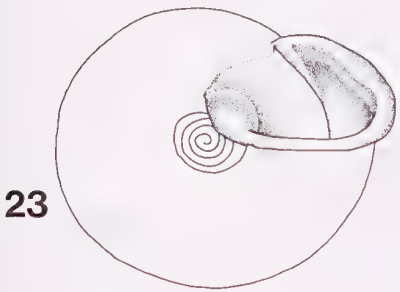
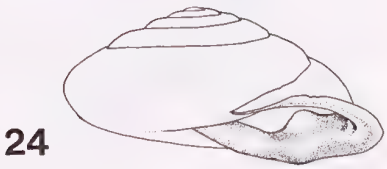


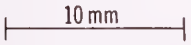
FIGURE 20. Terminal genitalia of *Ningbingia australis elongata*, new subspecies. FMNH 205092. WA-668, isolated hill 2.9 km north of Tanmurra Creek, south tip of North Ningbing Ranges. 26 May 1980. Penis sheath opened and apex of penis opened to show internal wall sculpture. Scale line equals 5 mm.



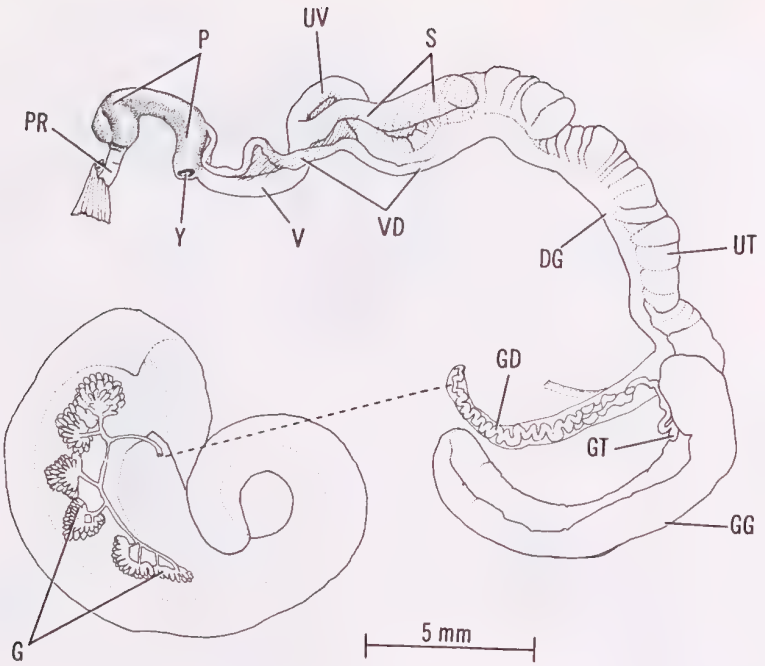








FIGURES 21-25. Shells of *Cristilabrum rectum*, new species and *C.* probably new species: 21-23, holotype of *C. rectum*. WAM 151.84. WA-1005, isolated ridge northeast of The Gorge, Central Ningbing Ranges; 24-25, side and umbilical views of *Cristilabrum*, probably new species. WAM 154.84. WA-1033, high limestone pillars, southwest of Ningbing Bore, South Ningbing Ranges. Scale lines equal 10 mm.



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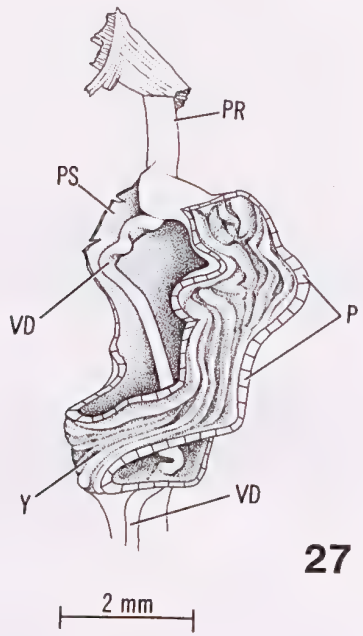


27

FIGURES 26-27. Genitalia of *Cristilabrum rectum*, new species. FMNH 211791. WA-1005, isolated ridge north of The Gorge, Central Ningbing Ranges. 25 May 1984: 26, whole genitalia; 27, interior of penis. Scales lines as marked.

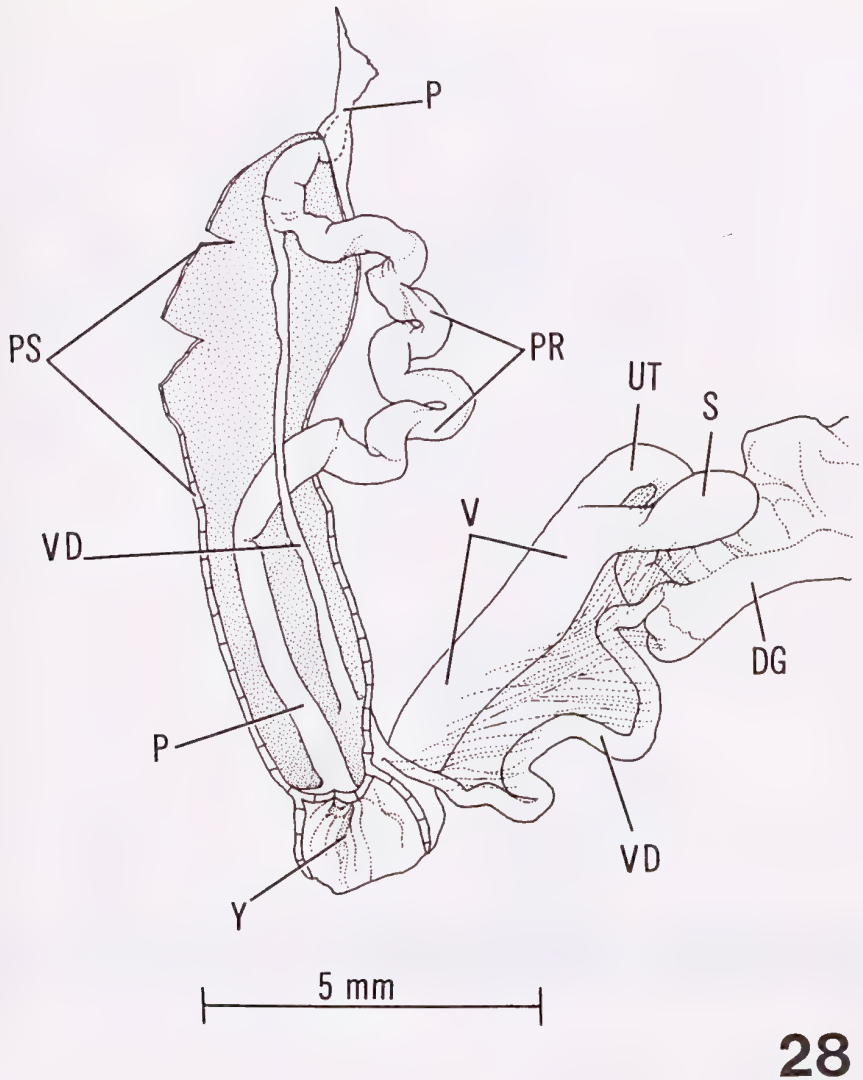
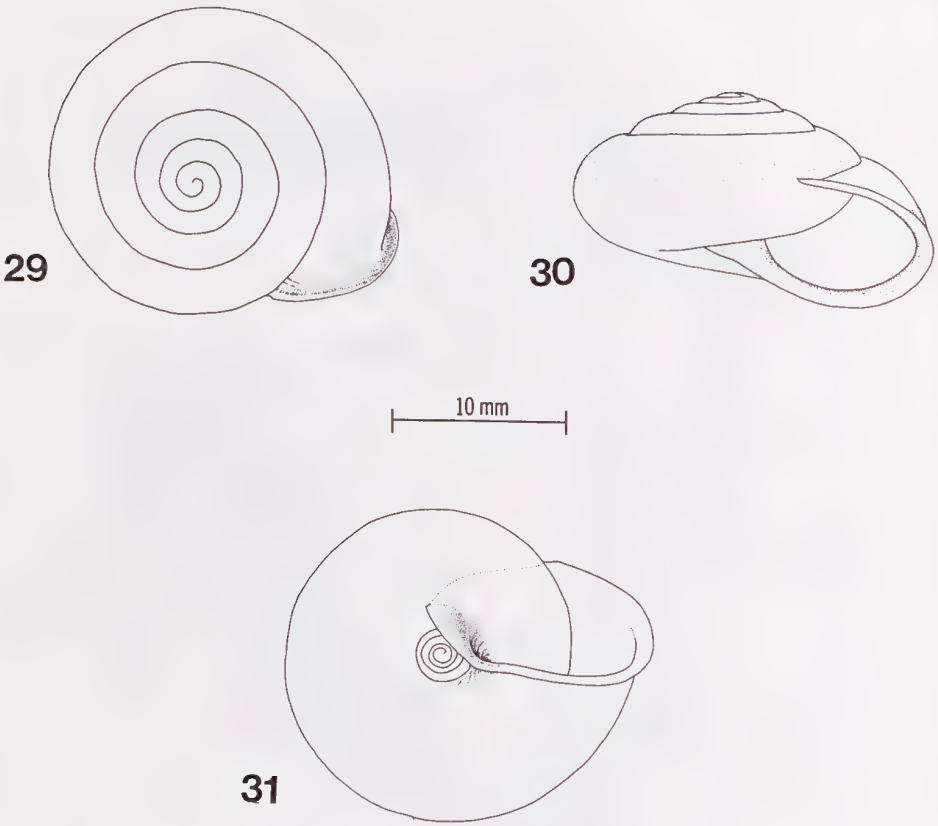
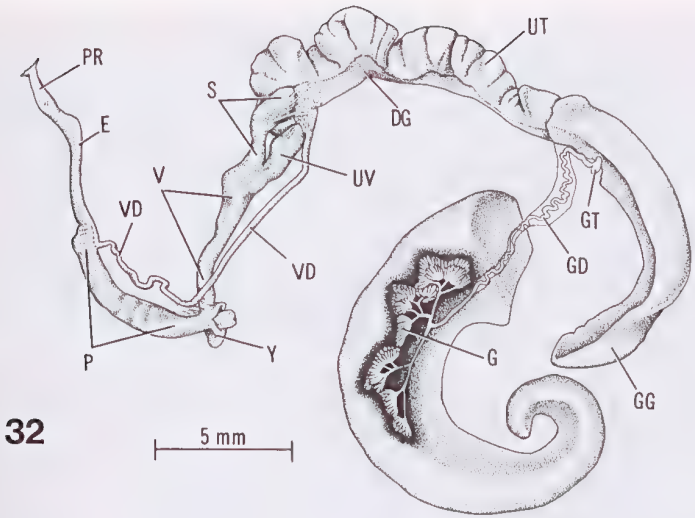
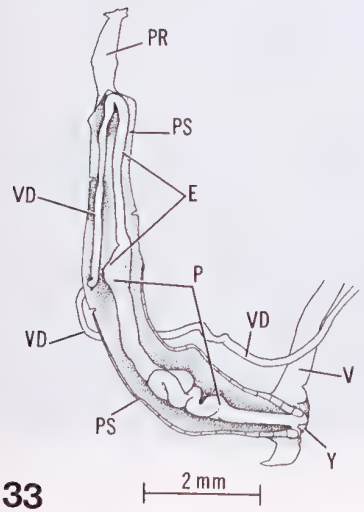


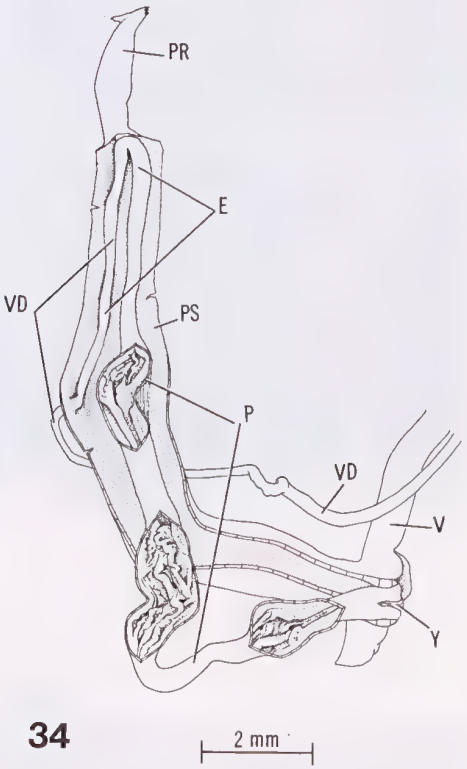
FIGURE 28. Genitalia of *Cristilabrum,* probably new species. FMNH 211876. WA-1033, high limestone pillars, southwest of Ningbing Bore, South Ningbing Ranges. 31 May 1984. Penis sheath opened. Scale line equals 5 mm.



FIGURES 29-31. Holotype of *Mesodontrachia cockburnensis*, new species. WAM 157.84. WA-988, valley on southwest face of Cockburn Range, opposite Pentecost River, south of Wyndham. Scale line equals 10 mm.







FIGURES 32-34. Genitalia of *Mesodontrachia cockburnensis*, new species. FMNH 211736. WA-988, valley on southwest face of Cockburn Range, opposite Pentecost River, south of Wyndham. 24 May 1984: 32, whole genitalia; 33, penis complex with sheath opened; 34, interior of penis. Scale lines as marked.

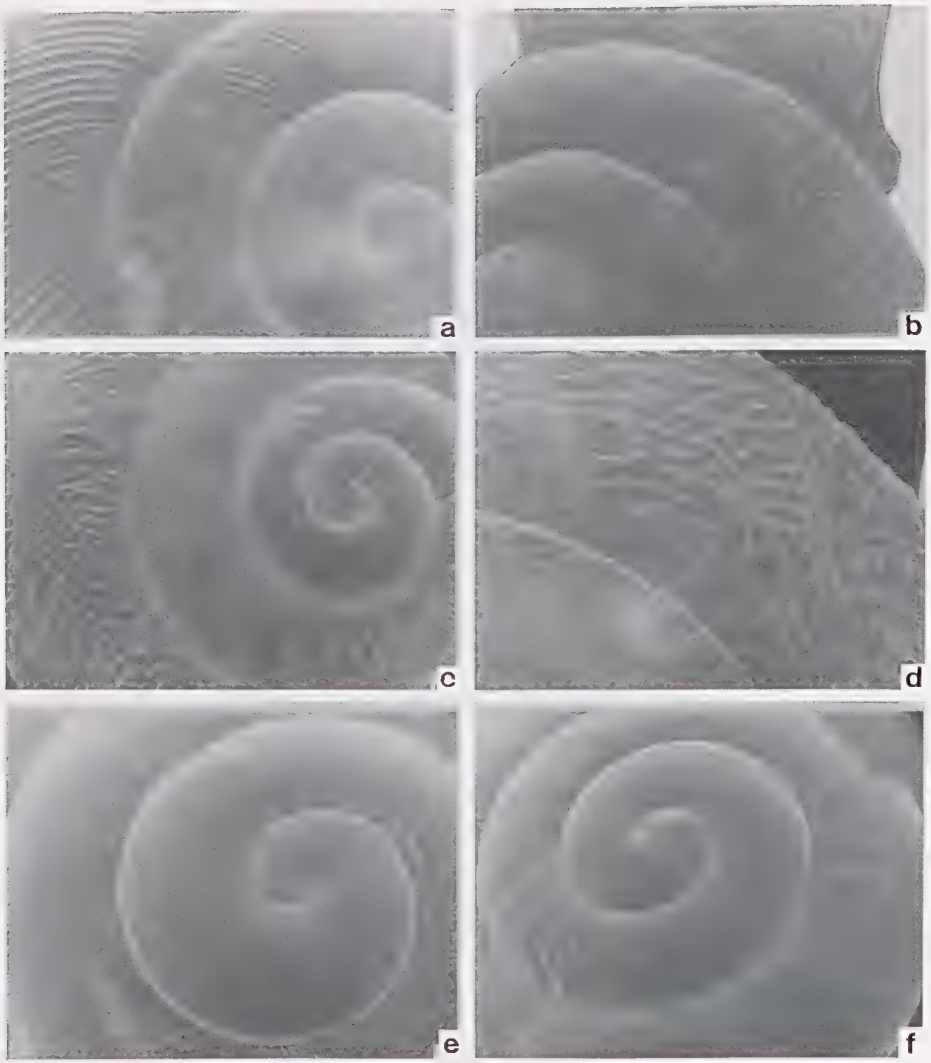


PLATE 1

Shell sculpture: a, *Amplirhagada cambridgensis*. WA-985, Lyne River, Cambridge Gulf. FMNH 211876. Apex and early spire, 18.5X; b, *Amplirhagada osmondi*. PC-43, Palms Yard. FMNH 215266. Apex and early spire, 16.8X; c-d, *Ordtrachia elegans*. WA-984, southwest of Point Spring, Weaber Ranges. FMNH 211733. c, Apex and early spire, 17.4X, d, mid- and lower spire of juvenile, 17.8X; e, *Ningbingia australis elongata*. WA-668, hill southeast of tip, North Ningbing Ranges. FMNH 205092. Apex and spire of subadult, 21.3X; f, *Cristilabrum* rectum. WA-1005, ridge north of The Gorge, Ningbing Ranges. FMNH 211791. Apex and early spire, 17.8X.

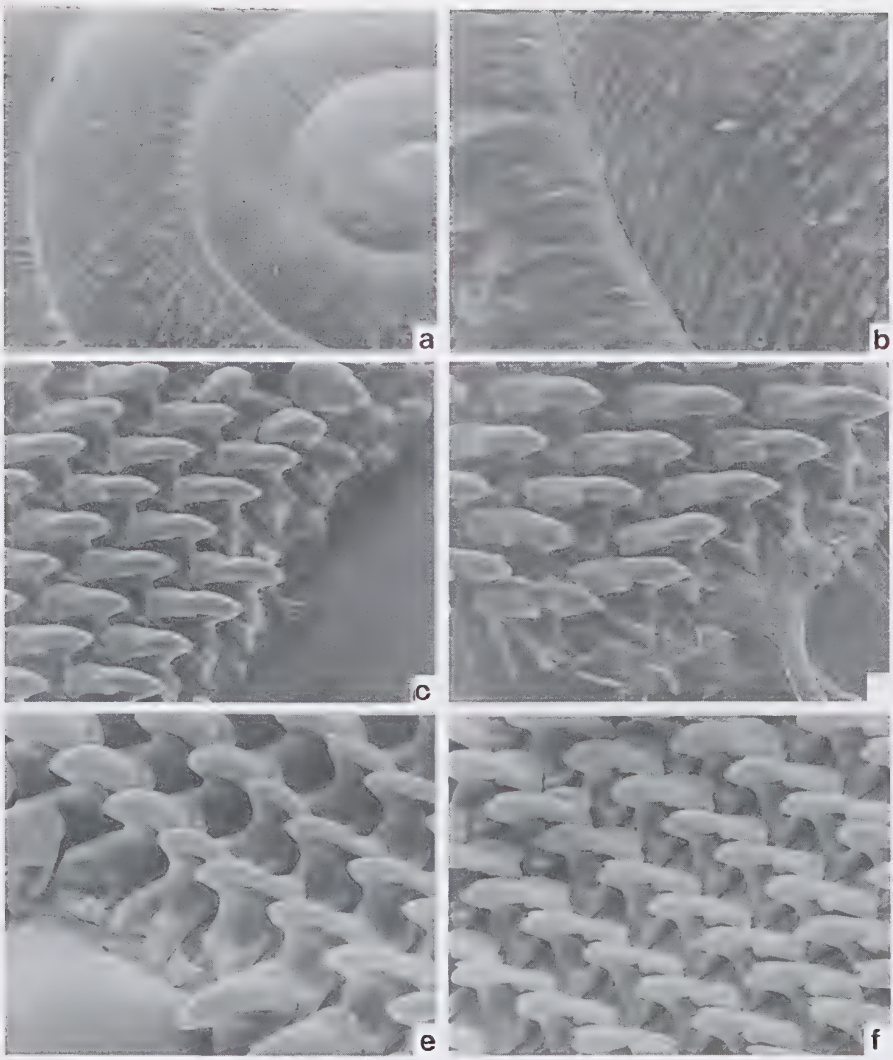


PLATE 2

Shell sculpture and radular teeth: a b, *Mesodontrachia cockburnernsis.* WA-988, Cockburn Ranges, near Wyndham. FMNH 211736. a, Apex and early spire, 19.2X, b, Microsculpture on mid-spire, 90X; c-d, *Amplirhagada cambridgensis.* WA-985, Lyne River, Cambridge Gulf. FMNH 211718. c, Central and early lateral teeth, 405X, d, Transition between lateral and marginal teeth, 540X; e-f, *Amplirhagada osmondi.* PC-43, Palms Yard. FMNH 215266. e, Central and early lateral teeth, 680X; f, Transition between lateral and marginal teeth, 660X.

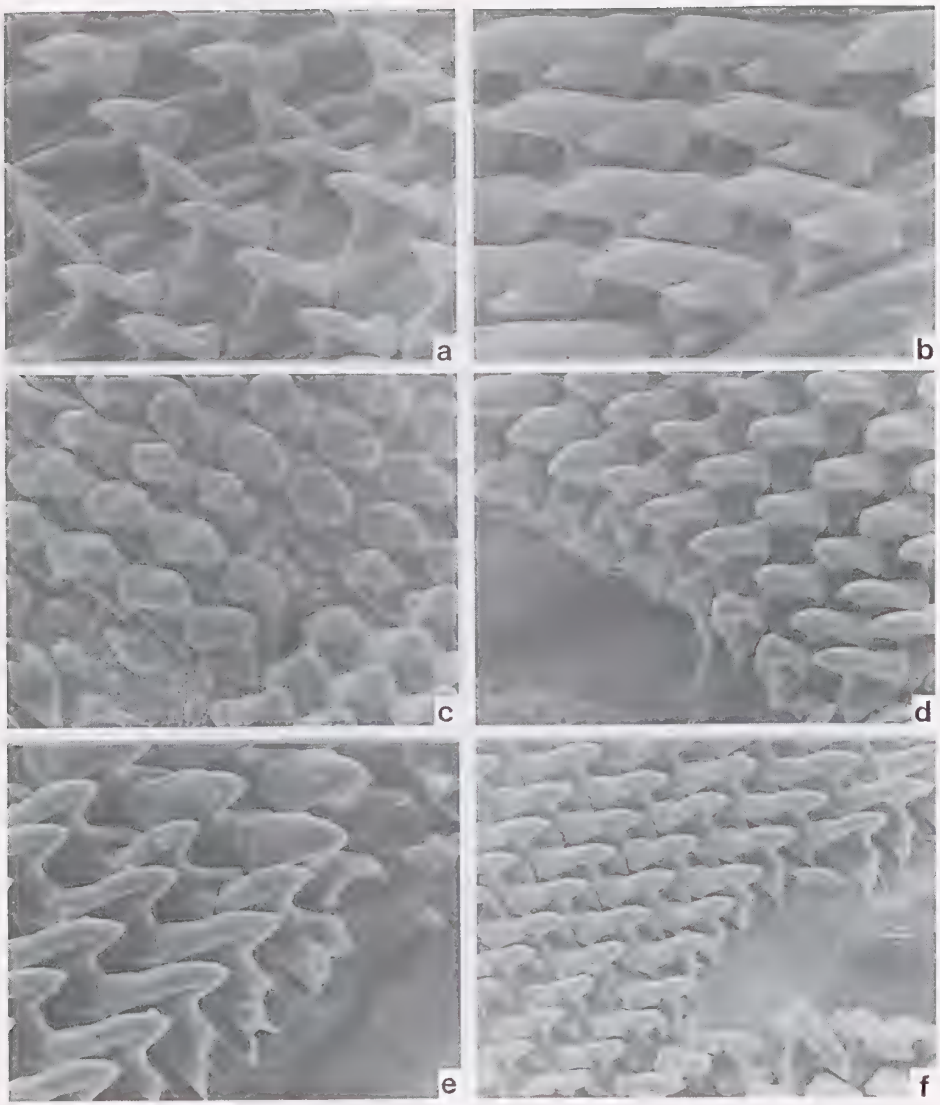


PLATE 3

Radular teeth: a-b, *Ordtrachia elegans*. WA-987, southwest of Point Spring, Weaber Ranges. FMNH 211734. a, Central and early lateral teeth from near posterior end of radula, 840X; b, Transition between lateral and marginal teeth, 1175X; c-d, *Cristilabrum rectum*. WA-1005, ridge north of The Gorge, Ningbing Ranges. FMNH 211791. c, Worn central and lateral teeth from anterior end of radula, 420X; d, Unworn central and early lateral teeth from middle of radula, 445X; e-f, *Mesodontrachia cockburnensis*. WA-988, Cockburn Range, near Wyndham. FMNH 211736. e, Central and early lateral teeth, 580X; f, Transition between lateral and marginal teeth, 390X.